PHYSICAL AND CUP QUALITIES OF COFFEE (*Coffea arabica* L.) AS AFFECTED BY VARIETIES AND SHADE LEVELS AT JIMMA, SOUTHWEST ETHIOPIA.

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Physical and Cup Qualities of Coffee (*Coffea arabica* L.) as Affected by Varieties and Shade Levels at Jimma, Southwest Ethiopia.

By

Tigist Eshetu Kebede

A Thesis

Submitted to the School of Graduate Studies of Jimma University, College of Agriculture and Veterinary Medicine Department of Horticulture and Plant Sciences

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As thesis research advisors we hereby certify that we have read and evaluated the thesis prepared under our direction by Tigist Eshetu, entitled '**Physical and Cup Qualities of Coffee (*Coffea arabica* L.) as Affected by Varieties and Shade Levels at Jimma, Southwest Ethiopia'** and recommend that it be accepted as fulfilling the thesis requirement.

Adugna Debela (PhD Scholar)

Major Advisor	Signature	Date

Kassaye Tolessa (PhD Scholar)

Co-advisor	Signature	Date

As members of the examining board of the final MSc open defence, we certify that we have read and evaluated the thesis prepared by Tigist Eshetu entitled '**Physical and Cup Qualities of Coffee (*Coffea arabica* L.) as Affected by Varieties and Shade Levels at Jimma, Southwest Ethiopia'** and recommend that it be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Horticulture (Coffee, Tea and Spices).

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Name: Tigist Eshetu Kebede

Place: Jimma University, Jimma Date of submission: July 2015

Signature: ______________________

BIOGRAPHICAL SKETCH

Tigist Eshetu Kebede was born on November 24, 1991 at Jimma town, Oromiya region. She attended her Primary, Secondary and Preparatory Schools at Kito, Seto Semero and Jimma Preparatory Schools, respectively. After successful passing of the Ethiopian Entrance Exam, she joined Bahir Dar University, College of Agriculture and Environmental Science in 2009 and graduated with BSc degree in Plant Science in 2014.

After her graduation, she was employed by Ministry of Agriculture and Rural Development office, department of coffee development section and served for 1 and ½ years as Coffee, Tea and Spices in Bench Maji Zone, Meinit Shasha Woreda. Then she joined School of Graduate Studies of Jimma University in 2014 to pursue her studies leading to Master of Science in Horticulture (Coffee, Tea and Spices).

DEDICATION

I dedicate this thesis manuscript to my father and my mother as well as for my husband for nursing me with affections and love and their dedicated partnership for the success of my life.

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ACRONYMS AND ABBREVATIONS

CDMIP	Coffee Development and Marketing Improvement Plan
CFC	Common Fund for Commodities
CIP	Coffee Improvement Project
CLU	Coffee Liquoring Unit
CQPPHMP	Coffee Quality Pre and Post Harvest Management Practices
CSA	Central Statistics Authority
DA	Development Agent
ECEE	Ethiopia Coffee Export Enterprise
ECMC	Ethiopia Coffee Marketing Corporation
ECPSE	Ethiopia Coffee Purchase and Sale Enterprise
ECX	Ethiopia Commodity Exchange
FAO	Food and Agriculture Organization of the United Nations
FTC	Farmers Training Center
ITC	International Trade Center
ICO	International Coffee Organization
IPM	Integrated Pest Management
ISO	International Standard Organization
JARC	Jimma Agricultural Research Center
JUCAVM	Jimma University, College of Agriculture and Veterinary Medicine
QSAE	Quality and Standards Authority of Ethiopia
SAS	Statistical Analysis System

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M.Sc. Thesis Research

By

Tigist Eshetu

Major advisor: Adugna Debela (PhD Scholar)
Co-advisor: Kassaye Tolessa (PhD Scholar)

ABSTRACT

Despite efforts were made to assess the effect of shade on coffee production and quality, there is lack of profound assessment works which identified optimum shade level on physical and cup qualities of Arabica coffee in Ethiopia. The present study assessed the changes in some physical and cup qualities of Arabica coffee using three cultivars of Arabica coffee under four contrasting light regimes (0% shade, 30% shade, 50% shade and 70% shade) using artificial net covering in split plot design. Most of the physical and cup quality parameters increased significantly (P < 0.05) at 50% and 70% shade level. However, most of the cup quality evaluation showed a decreasing trend as the shade level increased from 50% to 70%. Coffee variety 744 grown under 50% artificial shade registered relatively better values in its aroma, flavour, aftertaste, balance, total cup quality, overall cup preference and total speciality cup quality while coffee variety 74110 showed the lowest values under open sun for the above parameters. Whereas under 70% shade level, the values for bean size, 100 bean weight as well as primary & secondary defects were relatively higher although it is statistically non-significant. Non-significant variations were observed in odour, cup cleanness, acidity and body. Aroma, flavour, aftertaste, balance and overall cup preference are the most predominant cup qualities of Arabica coffee in all the varieties studied, being the highest in the beans grown under 50% shade followed by 70% shade. The present investigation has important implications in terms of coffee shade tree management to help farmers increase coffee plantation sustainability, produce coffee beans of superior physical and cup qualities and ultimately improve their revenues. Thus, for sustainable production of market oriented best quality coffee among others, careful selection of suitable coffee cultivars and shade levels under appropriate agricultural management practices is very important. Based up on the present study, variety 744 under 70% shade level and variety 744 under 50% can be suggested for farmers of the study area to improve the raw qualities and cup qualities, respectively to improve the raw qualities of Arabica coffee. However, further studies involving more Arabica coffee cultivars under various shade levels should be conducted to investigate the overall qualities of Arabica coffee.

***Keywords*:** coffee quality, coffee variety, aroma, shade level

1. INTRODUCTION

Coffee *(Coffea arabica* L.) is the single most important agricultural commodity crop that comes after petroleum in the world market (Aske *et al*., 2009). It belongs to the family Rubiacea (Illy and Viani, 2005) and consists more than one hundred species. Coffee is produced in more than 60 countries; three of them account for more than half of the world's production: Brazil, Vietnam and Columbia (Illy and Viani, 2005). The world annual coffee production is around seven million tons, of which Brazil produces one-third. The share of Africa in the world production is about 12.1% (FAOSTAT, 2013; Vaast *et al*., 2006) whereas Ethiopia's share is estimated to be 4.9% (Yonas, 2014). Arabica Coffee, whose centre of origin and diversity is Ethiopia, accounts for more than 62% of the world coffee production and 90% of the world coffee market (Taye, 2012). It accounts 25% of Ethiopia's foreign exchange earnings and 25% of the population's employment opportunity (Taye, 2012).

Ethiopia is the largest coffee producer in Africa: Around 400,000 tons per annum and all of it is Arabica. Wild trees of Arabica coffee are still the primary source of harvested coffee. Ethiopia and Brazil are the only coffee producing countries that consume a significant portion of their production; around 50% of the production for Ethiopia (Mekonnen, 2009).

Besides, coffee is a truly global commodity and Ethiopia's number one source of foreign exchange (Tadesse and Feyera, 2008). The vast majority of coffee is exported as green beans for roasting in consuming countries. Ethiopia plays an important role in the 'global value chain' because of the fine quality of its coffees (Mekonnen, 2009) but the total share of its coffee export in the world trade is small. The national average yield (250- 475 kg/ha/annum) is very low due to several production constraints including inappropriate management and climatic factors (Taye, 2012). Annual coffee export from Ethiopia is around 200,000 tons valued at around US$ 500 million. Coffee production is mainly in west and south Ethiopia, around 90% based on smallholders. An estimated 1.2 million smallholder farmers are engaged in coffee production and the quality of Arabica coffee from Ethiopia is generally good. For instance, some regions (e.g. Sidamo, Yirgacheffe and Harar) receive very high prices (Mekonnen, 2009).

A key opportunity in increasing coffee exports lies in improving quality. Nowadays, coffee quality (both physical and cup quality attributes) is the most appreciated characteristic in the international coffee trade (Subedi, 2010). Hence, it is a determining factor in the price of coffee beans. In fact, in Ethiopia the quality of a batch of coffee beans commonly referred to as a "lot" establishes whether it can be exported or must be sold locally. Moreover, quality defines whether the lot will be bought at a standard commodity price or may acquire a "specialty" price which is much higher. The factors that determine quality are numerous, yet in a coffee bean's entire journey from the field to the final drinking-cup; quality is foremost made or lost at the farm level (Avelino *et al*., 2005).

Quality improvement in coffee starts on the farm through improvement of the growing environment and management conditions. Coffee quality is a complex process in which a great number of factors and interactions intervene at various intensities. One of the coffee quality parameter is coffee cup quality test. Cup quality is a cross-cutting priority that runs through all world coffee research projects in order to increase the understanding and the improvement of this major market driver (Avelino *et al*., 2005).

Various studies have identified key factors that determine coffee quality. Altitude, shade, coffee variety, agricultural management, bean maturity, processing (wet or dry) and beverage preparation are the most important ones (Vaast *et al*., 2005). The role of these factors has been evaluated individually under specific conditions.

Coffee is shade-loving crop, which is naturally growing as an under-story shrub in its original ecology in the tropical high rainforests of south and south-western Ethiopia (Vaast *et al*., 2006). It has been assumed, and to some extent documented, that the shade tree-coffee association is beneficial in that under tropical conditions, shade is very much essential to prevent over-bearing, suppress weed growth, reduce the intensity of sunlight and temperature, combat drought effects, to maintain the moisture levels in tissues and to protect the coffee plants from low temperature and wind velocities. Adequate shade improves soil fertility by way of returning large amounts of leaf litter to the underneath soil, nitrogen fixation and retains soil moisture (Desse, 2008).

Shade trees play an important role in coffee growing regions of the world owing to the valuable impact of coffee agro-forestry systems on the environment and natural resources (preservation of biodiversity, soil conservation, water quality, carbon sequestration). Studies in Guatemala and Costa Rica (Muschler, 2001) have demonstrated that elevation and shade improved coffee quality owing to cooler climatic conditions and probably a longer ripening period of coffee berries. In 1999 a collaborative research effort was developed in Central America to compensate low coffee market prices by promoting coffee agro-forestry systems to improve coffee farmers' incomes through diversification (timber production), production and commercialisation of high-quality coffee and payment of incentives for environmental services provided by these ecologically sound coffee systems (Muschler, 2001). Within this research framework, several scientific investigations have been undertaken to determine the importance of factors such as microclimatic conditions, tree productivity, berry position within the canopy, shade management and fertilisation regimes on coffee tree physiology and beverage quality (Vaast *et al*., 2006).

Under Central American condition, it has been clearly acknowledged that shade is the determining factor with the greatest influence on coffee quality (Vaast *et al*., 2005; Lorena Soto *et al*., 2000). Study conducted in Costa Rica indicated that fruit weight and bean size increased significantly when shade intensity was increased from 0% to 80% under different coffee varieties. On the same study, it was indicated as if shade promotes slower and more balanced filling and uniform ripening of berries, thus yielding a better-quality product than un-shaded ones; however the specific shade level influences have not been indicated.

Another study from the same country revealed that shade (at 45%) positively affected bean size and composition as well as beverage quality by delaying berry flesh ripening. Higher sucrose, chlorogenic acid and trigonelline contents in sun-grown beans pointed towards incomplete bean maturation and explained higher bitterness and astringency of the coffee beverage (Yigzaw, 2006). Another study carried out in Mexico reported as if shade tree cover had a positive effect between 23 and 38% shade cover and yield was then maintained up to 48% (Lorena Soto *et al*., 2000).

According to the study conducted at Manna district, Southwest Ethiopia have indicated that coffee beans developed under shaded condition were heavier and larger in size (148 gm/1000 beans) and had better liquor taste (65%) than those developed under direct sun light (134 gm/1000 beans) and (50% liquor taste), respectively (Adugna and Paul, 2011).

In addition to shade levels, varietal difference is another important parameter that could be considered. There is wide difference among varieties for qualities within Arabica coffee types (Agwanda *et al*., 2003; Fox *et al*., 2013; Desse, 2008; Behailu *et al*., 2008). Both shade and varietal differences influence both physical and biochemical processes and hence determine the concentration of biochemical compounds such as chlorogenic acids, trigonelline, sugar and fat matter in coffee beans during their developmental stages (Avelino *et al*., 2007; Vaast *et al*., 2005).

Despite the role coffee plays in the national economy and in spite of the fact that Ethiopia is home of Arabica coffee, in-depth research work to improve its quality has not yet been undertaken apart from the limited selection work done to develop varieties having fine flavour. Results of studies in this regard illustrated that there are peculiar Arabica coffee types in Ethiopia which exhibit fine cup taste (Behailu *et al*., 2008; Desse, 2008). But apart from fineness in flavour, assessing specific shade levels for specific Arabica coffee varieties in cup quality is important to secure market preferences. Moreover, limited information is available on the interactions between varieties and shade levels and their additive importance on the final quality of coffee beans to understand and improve coffee physical and cup qualities. In line with the increasing focus to quality oriented coffee production and trading system, it is an agenda of top priority to assess the physical and cup qualities.

Hence, this study is unique because it is the first of its kind to present information on effect of shade levels on the quality of various Arabica coffee cultivars in Ethiopia, which is currently not available in the published literature, and thereby fills a gap. Therefore this study was designed with the following objectives:

- To examine the influence of different coffee varieties and shade levels on physical and cup characteristics of Arabica coffee at Jimma.

- To identify the best variety and optimum shade level for the better physical and cup qualities of Arabica coffee.

2. REVIEW OF LITERATURES

2.1. Coffee Quality

Quality is a trait difficult to define. According to any dictionary, it is an inherent or distinguishing characteristic. The International Organization for Standardization (ISO) describes quality as the ability of a set of inherent characteristics of product, system or process to fulfil requirement of customers and other interested parties (ISO, 2000). These inherent characteristics can be called “attributes”.

There are different views of expressing quality. ITC (2002) defines that the quality of a parcel of coffee comes from combination of the botanical variety, topographical conditions, weather conditions, and the care taken during growing, harvesting, storage, export preparation and transport. On the other hand, for coffee, the definition of quality and the attributes considered have probably evolved through the centuries. Now days, according to Lorey *et al*. (2006), this definition varies along the production to consumer chain:

- At the farmer level: coffee quality is combination of production level, price and easiness of culture;

- At the exporter or importer level: coffee quality is linked to bean size, lack of defects, regularity of provisioning, tonnage available, physical characteristics and price;

- At the roaster level: coffee qualities depend on moisture content, stability of the characteristics, origin, price, biochemical compounds and organoleptic quality. It should be noted that each consumer market or country may define its own organoleptic qualities;

- At the consumer level: coffee quality deal with price, taste and flavour, effect on health and alertness, geographical origin, environmental and sociological aspects (organic coffee, fair trade, etc) (Lorey *et al*., 2006).

In recent years, different coffee producing countries have tremendously expanded their production and export volume (Behailu *et al.*, 2008). According to the current context of overproduction and low prices of the coffee market, improvement of coffee quality could provide the coffee chain with a new momentum (Leroy *et al*., 2006). Production and supply of coffee with excellent quality seems more crucial than ever before for coffee exporting countries. Consequently, some countries consider assessment of coffee quality as important as disease resistance and productivity in their coffee variety development program (ITC, 2004). In view of the present situation, making effort to overcome challenges and threats only through expansion of production does not seem visible for countries like Ethiopia. Thus, it has been repeatedly mentioned at various forum that provides good quality coffee is the only way out and viable option to get into the world market and to remain competitive (Behailu *et al.*, 2008).

Coffee is the most important crop in the national economy of Ethiopia and the leading export commodity. Ethiopia is well known not only for being the home of Arabica coffee, but also for it is very fine quality coffee acclaimed for its aroma and flavour characteristics. The coffee types that are distinguished for such unique characteristics include Sidamo, Yirgachefe, Hararghe, Gimbi and Limu types (Workafes and Kassu, 2000). However, coffee produced in some parts of Ethiopia, especially from Harar and Yirgachefe, is always sold at a premium price both at domestic and international coffee markets because of its distinctive fine quality (Chifra *et al*., 1998; ITC, 2002) and appropriate processing approach.

More specifically, ISO (2004) defined a standard for green coffee quality (ISO 9116 standard) as, it requires several pieces of information, like the geographical and botanic origins of the coffee, the harvest year, the moisture content, the total defects, the proportion of insect-damaged beans and the bean size. These ISO standards define methods of measurements for several of these qualities such as, defects, moisture content, bean size, some chemical compounds and preparation of samples to perform cup tasting. According to the definition of quality and standards authority of Ethiopia (QSAE) (2000) a quality is conformance with requirements or fitness for use in which the parties involved in the industry (customer, processor, supplier, etc) should agree on the requirements and the requirements should be clear to all stake holders involved in the process. On the other hand, Coffee Quality control and auction Center was established with a key objective of maintaining coffee quality control, which in turn facilitates the coffee marketing system to be standard based, and for the betterment /proper functioning of the long coffee supply chain of Ethiopia (Endale, 2008).

Coffee has only one value to give the consumer pleasure and satisfaction through flavour, aroma and desirable physiological and psychological effects (Yigzaw, 2006). Therefore coffee quality, especially liquor or cup quality, determines both the relative price and usefulness of a given quantity of coffee (Agwanda *et al*., 2003). Cup quality, often referred to as drinking quality or liquor quality, is an important attribute of coffee and acts as yardstick for price determination (Muschler, 2001; Agwanda *et al*., 2003).

2.2. Factors Affecting Coffee Quality

Various attempts have been made to determine the importance of numerous factors affecting growth and bean quality in coffee agro-ecosystems, including climatic conditions, shade management, fertilization regimes, and adequate pruning (Wintgens, 2004).

Cup quality is a complex characteristic which depends on a series of factors such as the species or variety (genetic factors), environmental conditions (ecological factors), agronomical practices (cultivation factors), processing systems (post-harvest factors), storage conditions, industrial processing, preparation of the beverage and taste of the consumer (Moreno *et al*., 1995). Coffee quality is of critical importance to the coffee industry. Quality coffee is a product that has desirable characteristics such as clean raw and roasted appearance, attractive aroma and good cup taste (Behailu *et al*., 2008).

However, in Ethiopia the quality of coffee produced by farmers has been deteriorating from time to time. Moreover, factors that determine coffee quality are genotypes, climatic conditions, and soil characteristics of the area, agronomic practices, harvesting methods and timing, post harvest processing techniques, grading, packing, storage conditions and transporting, all contribute either exaltation or deterioration of coffee (Behailu *et al*., 2008). Similarly, Damanu (2008) reported coffee quality as a combination of the botanical variety, topographical conditions, and climatic conditions and care taken during growing, harvesting, storage, exports preparation and transport. According to the author botanical variety and topographical conditions are constant and therefore dominate the inherent characters of a coffee where as other factors except climatic conditions can be influenced by human being and are a key factor in determination of the end quality of a green coffee. Furthermore, inadequate systems of harvesting, processing, storage and transportation are responsible for the wide spread failure to maintain the inherent quality of coffee produced in Ethiopia (Alemayehu *et al*., 2008)

2.2.1. Climatic and soil factors

The environment has also a strong influence on coffee quality (Decasy *et al*., 2003). Altitude, daily temperature fluctuations, amount and distribution of rainfall and the physical and chemical characteristics of the soils are very important factors. Climate, altitude, and shade play an important role through temperature, availability of light and water during the ripening period (Decasy *et al*., 2003). Rainfall and sunshine distributions have a strong influence on flowering, bean expansion, and ripening (Harding *et al*., 1987).

The slowed-down ripening process of coffee berries at higher elevations (lower air temperatures), or under shading, allows more time for complete bean filling (Vaast *et al.*, 2006), yielding beans that are denser and far more intense in flavour than their neighbours grown at lower altitudes (or under full sunlight). The slower maturation process should therefore play a central role in determining high cup quality, possibly by guaranteeing the full manifestation of all biochemical steps required for the development of the beverage quality (Silva *et al.*, 2005). For instance, chlorogenic acids and fat content have been found to increase with elevation in *C. arabica* (Bertrand *et al.*, 2006). Besides the beneficial effect of longer duration of the bean-filling period, a larger leaf area-to-fruit ratio (better bean-filling capacity) may also be linked to superior cup quality (Vaast *et al*., 2006).

The role of soil types has been well studied and it is generally admitted that the most acidic coffee quality is grown on rich volcanic soils (Harding *et al*., 1987). The perceived acidity of coffee brews has always been recognized as an important attribute of coffee quality. Acidity is typically a highly valued quality especially in Central American and some East African coffees (Yigzaw, 2006). Sourness, however, is an extreme of acidity and can be considered as defect. Acidity has been correlated with coffees grown at very high altitudes and in mineral rich volcanic soils. On top of this, Yigzaw (2006) reported that if other factors are kept constant, better quality coffee can be found at higher altitudes, while low land coffee were found to be somewhat bland, with considerable body. Moreover, coffee from high altitude areas was more acidic, with better aroma and flavour.

Woelore (1993) reported that for Ethiopian conditions an underwater fermentation technique and the time for fermentation for different agro-ecologies are recommended. According to the author mucilage degradation washed at the first, second, third, or after the third day from pulping in the altitudinal range 1200 m and below, 1200-15000 m, 1500-1800 m and above 1800 m, respectively, for varying fermentation practices. Walyaro (1983) reported that factors such as total rainfall, relative humidity, maximum-minimum temperatures with effect on water vapor content of the air and storage duration, greatly influence storability and quality of stored parchment coffee. Periods of prolonged drought may also result in lower quality beans (Wintgens, 2004). Most of the coffee tasters agree now that there is very little or no difference in flavour at all between the Arabica pure breeds cultivated under similar agro-climatic conditions (Wintgens, 2004).

2.2.2. Pre-harvest and harvest factors

Yigzaw (2006) reported that in South America, coffee grown with heavy application of nitrogen fertilizer had poorer, lighter and thinner quality than that from unfertilized fields. An excess of nitrogen increase the caffeine content, resulting in a more bitter taste of the brew. The caffeine and chlorgenic acid contents of the beans are not affected by the levels of phosphorus, calcium, potassium and magnesium in the soil (Wintgens, 2004). A lack of zinc will lead to the production of small light grey-colored beans, which will produce poor liquor (Wintgens, 2004). On the other hand, magnesium deficiency had an adverse effect on cup quality (Mitchell, 1988). High concentration of calcium (>0.11%) and potassium (>1.75%) in the beans is associated with a bitter and “hard” taste (Wintgens, 2004). Chane (1999) reported the use of decomposed coffee husk at a rate of 10 ton ha -1 (4 kg tree -1 on dry weight basis) was found to be superior in terms of yield performance of coffee trees. A significant improvement in growth and yield of mature coffees was reported in response to coffee pulp and husk compost application. On the other hand, there is no correlation between the phosphorus content and the physical and organoleptic quality of the bean (Wintgens, 2004) .On the contrary, repeated application of elephant grass or livestock manure resulted in an increased percentage of undesirable brown-colored bean and, thus, poor roasting characteristics. This effect was associated with a magnesium deficiency induced by the high potassium content of elephant grass as well as high concentration of potassium and calcium in manure (Wintgens, 2004). Good growth conditions (weed control, appropriate planting density and pruning) usually have a positive effect on bean size and flavour (Wintgens, 2004). The relationship between crop management and total coffee quality, however, has not yet been investigated in detail.

Pests and diseases attacks can affect the cherries directly or cause them to deteriorate by debilitating the plants, which will then produce immature or damaged fruits. Disease and insect attack (such as leaf miner and mites) may also result in lower quality beans (Wintgens, 2004). For instance, as reported by Wintgens (2004) the coffee berry borer *Hypothenemus hampii* feeds and reproduces inside the coffee beans and causes their quality to deteriorate. The antestia sting bug as a vector of micro-organisms damages the bean and causes a bitter flavour. Similarly, the fly *Ceratitis capitata* feeds on the mucilage and the cherry becomes infected with micro-organisms; the secondary bacterial infection causes a distinct potato flavour. OTA (Ochratoxin A) is a form of mycotoxin, produced as a metabolic product of *Aspergillus ochraceus*, *A. carbonarius* and strains of *A. Niger* reported to exist on coffee dried on bare ground (Eshetu and Girma, 2008).

Carvalho (1988) reported that shade trees did not improve cup quality. On the contrary, Muschler (2001) indicated that shade improved the appearance of green and roasted coffee beans as well as the acidity and body of the brew, especially for those produced in suboptimal (low altitude) coffee production zones, by promoting slower and balanced filling and uniform ripening of berries. Furthermore, Yilma (1998) observed that shade increased sugar concentration, which is an important factor for creating the aroma of coffee.

Apart from agronomic practices, cup quality is influenced by the age of the tree. Accordingly, Yigzaw (2006) reported that samples from young trees are likely to be mild and thin, but fine in flavour. Samples from old trees produce strong taste and a harsh characteristic brew. Medium aged trees, 15 to 20 years old, bear beans with good flavour as well as acidity and body (Yigzaw, 2006).

According to the results of studies by (Bertrand *et al.,* 2006; Vaast *et al*., 2006), tree physiology, plant age, and period of picking all interact to produce the final characteristics of the product. Indeed, it was found that tree age, location of the fruits within the tree, and fruits-to-leaves ratio had a strong influence on the chemical content of green beans. Maturation also has a strong influence on coffee quality. The main factor affecting natural coffee quality is harvesting method. It is widely agreed that traditional hand-picking and husbandry labour, as opposed to mechanical harvest, produce the best quality green coffee by decreasing the percentage of defects in coffee batches. Bertrand *et al.* (2006) observed that yellow or green cherries picked at the end of the picking season contain beans with a higher maturity level than red cherries of *C. canephora* picked at the start of the picking season. This can be seen in bean size, chemical contents, and cup quality. On the other hand, for *C. arabica* in Costa Rica, early picking of red cherries gives the best coffee (Bertrand *et al.*, 2006).

On the other hand, Endale (2008) pointed out that low caffeine content was found in bean harvested at immature stage (unripe) and in over-ripe coffee beans with conventional analysis using high performance liquid chromatography (HPLC). According to their findings this could be associated with slow metabolism of caffeine and its biodegradation at immature and over-ripe stages of fruit development, respectively.

2.2.3. Post-harvest factors

Depending on the post harvest processes, significant effects on coffee quality can be observed (Getu, 2009). Processing is a very important activity in coffee production and plays a crucial role in quality determination (Endale, 2008). Coffee is either processed by the wet or dry methods, which vary in complexity and expected quality of the coffee (Bertrand *et al.*, 2006). Both sun-drying as well as wet-processing methods are operated in Ethiopia, which accounts for 70% and 30% of coffee produced in the country, respectively (Jacquet *et al*., 2008).

According to Clifford (1985) wet processed Arabica is aromatic with fine acidity and some astringency, while dry processed Arabica is less aromatic and less acidic but with greater body. The perceived acidity of washed coffees is also significantly higher than the acidity found in naturally (dry) processed coffees. This is likely due to an increase in the body of naturally processed coffees relative to wet processed coffees since body masks the coffee's acidity (Yigzaw, 2006). Selmar *et al*. (2001) reported that cup quality evaluation of the roast coffees revealed that the dry and washed coffees could be distinguished with high significance. As their report the differences in quality of differently processed coffees of similar original material is due to the process taking place in the beans during processing. In the majority of the study area coffee is prepared using a dry processing (natural sundried) system, which is the first method by which the fresh cherries are harvested and sundried as a whole. Generally, farmers harvest selectively red cherries by picking them by hand; however a premature harvest can be sometimes carried out by strip picking for needs of cash and fear of thefts (Jacquet *et al*., 2008).

The second method is the wet processing method in which the fresh red cherries are processed in three stages i.e. removals of the pulp and mucilage, fermentation and washing, and drying of parchment coffee (CFC, 2004). The covering period during drying and depth of parchment layer affects the total time required to dry parchment coffee to an optimum moisture level. Behailu and Solomon (2006) identified parchment coffee dried at the highest drying depth (5 cm) gave the lowest value of cup quality, while the other drying depths (2, 3 and 4 cm) gave better values of cup quality. Then, parchment coffee is dried and ready for transport to where it is sold in the auctions (still in parchment form). Concerning its marketing, as all Ethiopian coffee, Jimma export coffee has to be channelled through the central auctions in Addis Ababa (CFC, 2004).

In washed coffee production, final quality among others is greatly dependent upon the fermentation process (Woelore, 1993). It has been confirmed that under-water soaking following ‘dry’ fermentation, i.e., two-stage fermentation enhances the appearance of both raw and roast coffees compared to ‘dry’ fermentation only (Behailu *et al*., 2008). According to their report post fermentation soaking for 24 hours produced better raw and roast appearance than either 8 or 16 hours soaking but extending the soak to 48 hours did not cause any further improvement to the raw and actually reduced the roast quality.

Natural fermentation of coffee is the function of many parameters, such as environmental, pH, temperature, micro flora and level of pollution in the water used, variety difference in the ripe cherries used for pulping, its geographical and cultural origin, the standard of picking and minor variations in the processing method (Behailu *et al*., 2008). Furthermore, Behailu and Solomon (2006) reported that coffee fermented under shade takes more time, shaded fermentation tanks help to achieve uniform fermentation process and better quality coffee than unshaded one.

However, assessment made on wet-processed Jimma coffee by Brownbridge and Eyassu (1968) revealed that it is very heterogeneous, containing beans of all shapes, sizes and plain liquor, probably because of such a mixture types characterized by small beans of a nice green color and exquisite aroma. As the authors reported neither plant genetics nor the environment can be modified, but effort should be concentrated on the very critical post-harvest practices such as harvesting, processing, drying, storing and transporting of coffee cherries, which are liable to be a major influence components of the quality of the cup. Length and condition of bean storage also affect cup quality (Yigzaw, 2006). Long time storage under high relative humidity and warm conditions increase bean moisture content and consequently reduce quality in terms of raw and roasted appearance as well as liquor (Woelore, 1995).

2.2.4. Institutional factors

The National Coffee Board of Ethiopia (NCBE) was the first institution responsible for coffee which was established in 1957 with the aim of upgrading coffee quality, stimulating cooperative production, establishing marketing associations, conducting research and dissemination of information on coffee production, processing and marketing. Then after, the plantations in the south-western part of the county were organized under south western Agricultural Development organization. Eventually coffee plantations were organized under the Ministry of Coffee and Tea

Development (Gari, 2002). From 1979 to 1989, coffee auction market had been operating under the control of the government, i.e. the government set ceiling price, which was not competitive. After the 1990 market policy reform, the auction market was made free and the individual exporters and the Ethiopia

Coffee Export Enterprise (ECEE) operates compositely by referring to the most recent world market price for Ethiopia coffee (Admasu, 2008). In 1993, the Ethiopia Coffee Marketing Corporation (ECMC) was restructured into two enterprises: the Ethiopia Coffee purchase and Sale Enterprise (ECPSE) and the Ethiopia coffee Export Enterprise (ECEE).

Though research on coffee have been conducted nationally for more than four decades by JARC, the target of coffee research in Ethiopia was to develop CBD (Coffee Berry Disease) resistant, high yielding and wide adapting varieties to release for major coffee growing areas of the country (Getu, 2009). Therefore, so far there was no extensive coffee quality research conducted in the country except on fermentation, drying depth and time of storage (Behailu and Solomon, 2006). Coffee Development and Marketing Improvement Plan in Ethiopia (CDMIP) was launched since 2003 to maximize the benefits driven from coffee by optimizing production and marketing systems of the industry (Alemayehu *et al*., 2008). According to their report, the small holding coffee farmers in particular could not able to make use of appropriate inputs and implement tools such as pruning shears, bow saw and drying materials largely due to unavailability, poor purchasing capacity and absence of appropriate credit systems. Effective Agricultural Extension services are of paramount importance for farmers to get timely advices and information on the availability, use and application of new, improved and modern agricultural inputs, technologies and practices. The Gomma and Manna Agricultural and Rural development offices are responsible to offer agricultural extension services. Under these offices, different experts with different professions were organized at all levels and Development Agents (DAs) at Farmers Training Center (FTC). The Development Agents at the FTC are responsible to give extension services to the farming community and they are accountable to the Woreda Agricultural offices.

According to Jacquet *et al*. (2008), prior to market liberalization washed coffee was subjected to intensive supervision and close monitoring with the aim of keeping its quality in respect to training and technical advices about quality cherries collection, processing, drying and storing to concerned groups. But, currently, the intensity of supervision is reduced because of various factors including limitation of logistics, financial and human resources above all, there are no cherries formal market areas and legally identified coffee purchasers, delay of collected cherries a day before delivered to washing station and narrow price difference between different coffee grades (Jacquet *et al*., 2008).

2.3. Effect of Shade on Quality of Coffee

Growing coffee under shade trees is one of the fundamental principles in traditional organic coffee growing systems (Beer *et al*., 1998). Shade trees reduce excessive light, mulching the soil with their litter and pruning, create hostile conditions for pests and diseases, harbour a variety of predatory animals (Beer *et al*., 1998), breaking the force of wind and heavy rainfall, controlling erosion on steep slopes, suppressing weeds, recycling of nutrients otherwise not available to the coffee and reducing nutrient leaching, preventing over-bearing and shoot dieback as a result of reduced light intensity, improving cup quality, particularly in ecologically sub-optimal coffee zones of high temperatures (Beer *et al*., 1998; Muschler, 2001). Arabica coffee is a self-pollinated plant initiating heavy flowers that rapidly develop to fruits (Anwar, 2010). During this period there is increasing carbohydrate absorption from both leaves and wood for flowers initiation and rapid fruits expansion. As a result roots are damaged, leaves are abscised and branches start dying from the tip and go back to the petiole. But, shade trees assist in maintaining coffee yields in the long term by reducing periodic over-bearing and subsequent die-back of coffee branches (Chanyarin, 2012). In addition, shading delays the maturation of coffee berries resulting in a better bean filling and larger bean size resulting in better coffee quality (Muschler, 2001; Adugna and Paul, 2011).

2.4. Management of Shade on Coffee

Though the effect of shade on coffee growth, yield and quality is not compromised, its optimum level should be managed. Inappropriate shade management in coffee will result in progressively lower yields with increasing shade intensity, due to a reduction in flowering nodes, inflorescences per node and flowers per inflorescence, competition for water between shade and coffee trees in seasonally dry regions, damage of the coffee trees by falling branches from the shade trees and occasional tree felling, additional labour costs for regularly pruning of over-head trees to avoid excessive shading and potential increase of some diseases (e.g. South American leaf spot) and insect pests (e.g. coffee berry borer) (Beer *et al*., 1998; Muschler, 2001).

Arabica coffee requires 50-60% of filtered shade for maintaining good consistent crop yield (Biruk, 2014). The canopy of permanent shade trees has to be regulated by undertaking the operations such as shade lopping, shade thinning and shade lifting depending upon the necessity and requirement to maintain optimum shade for the coffee plants (Lara-Estrada and Philippe, 2006). Shade trees are therefore recommended as a protective measure when environmental conditions can be difficult for coffee, particularly in areas which are exposed to high temperature, long drought, heavy rainfall and chance of hail**.** Arabica coffee is the most important source of foreign currency for many developing countries. Seventy percent of the world's coffee is contributed by smallholders in developing countries who grow coffee mostly on farms of less than hectares and intercrop coffee with other crops (Avelino *et al*., 2005).

Sidama and Gedeo Zones are the major coffee producing areas in the Southern region and coffee is grown as garden (cottage or smallholder) crop, intercropped with Enset (*Enset Ventricosum*) or under the evergreen shade trees of *Erythrina* Spp., *Milletia Ferruginea* and *Albezzia* Spp. (Mekonnen, 2009). Sidama and Yirgacheffe coffee types produced in these Zones possess unique quality, are largely preferred by Arabica coffee consumers and fetch premium prices in the world market.

Shade management ranges from coffee systems under natural unmodified forest cover over scattered multipurpose trees to highly controlled shade in commercial agro-forestry systems

(Perfecto *et al*., 2005; Vaast *et al*., 2005). Some work has been done to document the relationship between shade and coffee yield, e.g. Beer (1998) and DaMatta (2004) found positive effects in suboptimal locations, whereas Soto-Pinto *et al*. (2000) and Soto-Pinto *et al.* (2000) found negative effects when shade level was above 50%. He found that high shade (60-80%) coffee flowers equally well to the medium-shade (30-50%) in low-input coffee farms of Chiapas, Mexico. Results differ because the environmental factors and the coffee varieties examined vary among the studies, and issues of exact environmental needs are difficult to quantify because of the variation (Sturdy, 2005). Optimal shade levels are likely to be below 50%, especially for coffee that receives fertilization or supplemental irrigation. What is unknown is whether the trade-off of yield with bean size, flavour profile, or other aspects of quality, that can occur with shade results in a net benefit to the producer.

2.5. Genetic variation among varieties of Arabica coffee

The coffee genus includes more than one hundred different species between which a large variation in terms of chemical composition is observed (Clifford, 1995). Coffee produced from *C. Arabica* is known to have a good quality. This characteristic is clearly established for classical varieties like Caturra, Mundo Novo, and other pure lines obtained from pedigree selection. Walyaro (1983) showed the presence of large inherent difference among genotypes for bean and cup quality attributes. Van der Vossen (1985) also observed in which variation for cup quality character among varieties and crosses of Arabica coffee.

Based on organoleptic evaluation, introgressed lines of Arabica were found to produce good beverage quality (BQ) that was similar to the non-introgressed standard (Owuor, 1988; Moreno *et al*., 1995; Lorey *et al*., 2006). Some of the varieties had big sized beans and excellent cup quality, while the rest had small sized beans, lower cup quality and chemical content (Van der Vossen, 1985).

The worlds’ best quality coffee such as Harar and Yirgacheffe (ITC, 2002) are produced in the Eastern and Southern parts of Ethiopia, respectively. Likewise, farmers, consumers and agricultural development agents reported the presence of considerable cup quality variation among different Arabica coffee genotypes grown in north western Ethiopia (Yigzaw, 2006), thought not yet characterized for use and conservation in the region. The most striking association and identification for coffee is its point of origin. The more one knows about the coffee's origin, the more confident one can be about its uniformity and properties. That is the respective details about the coffee's origin are, country of origin, state or region where grown, port of embarkation, the name of the mille exporter, the name of the grower, and the location of the grower's plantation (Getu, 2009).

As harvesting method, post harvest procedures and the physiology of the plant itself affect coffee quality, its genetic origin (species and genotype) also greatly influence coffee quality (Leroy *et al*., 2006). Agwanda *et al*. *(*2003) compared four traits (acidity, body and flavour) and overall standard for their suitability as selection criteria for the genetic improvement of overall liquor quality. According to the author, based on correlation, repeatability and sensitivity analysis, flavour rating was recommended as the best selection criterion for genetic improvement of cup quality in Arabica coffee. The trait showed high genetic correlation with preference, was easy to determine organoleptically and had relatively high sensitivity in discriminating different coffee genotypes. The study of Yigzaw (2006) also revealed that coffee quality depends on genetic make-up and genes control the production of chemical compounds that behave as aroma agents either directly or as aroma precursors expressed during the roasting process. Hence, while selecting a cultivar to be planted; cup quality must be the first priority to be considered (Yigzaw, 2006).

Furthermore, Owuor (1988) and Moreno *et al*. (1995) improved the cup quality of different coffee genotypes with the assistance of professional coffee tasters. Both researchers observed close similarity among liquorers in ranking various cup quality characteristics of the cultivars, indicating that any one panel could be relied on selection for cup quality. Similarly, Agwanda *et al*. (2003) reported significant genotype x environment interaction effects on coffee bean and liquor quality. Walyaro (1983) reported relatively lower genotype x environment interaction effects on quality characters.

On the contrary, Van der Vossen (1985) reported non-significant genotype x environment interaction effects on quality characters, such as bean size and cup quality. Selvakumar and

Sreenivasan (1989) observed coffee cup quality variation ranging from good to excellent among 54 Arabica coffee accessions collected from Keffa, Ethiopia. The genotype is a key factor, since it determines to a great extent important characteristics such as the size and shape of the beans as well as their colour, chemical composition and flavour (Wintgens, 2004). The shape and structure of beans (elephant, pea bean and empty beans) are the result of both genotype and environmental factors (Wintgens, 2004).

2.6. Coffee quality assurance

The quality of a good cup of coffee, as experienced daily by millions of consumers is not a matter of chance. It is the result of a quality assurance program implemented by all the key players of the coffee production to consumer chain (Prodolliet, 2005). Quality as it is defined by ISO (2004) and Dessie *et al*. (2008), in its more practical definition, can be the ability of a product to satisfy consumer's expectation. They mainly include: Good cup quality characteristics (eg. aroma, flavour, body, acidity); Absence of off-flavours (e.g. mouldy, earthy, fermented, and chemical); Safety (absence of contaminants, like pesticides, mycotoxins); Environmental aspect (eg. organic product).

Not all these quality characteristics are a matter of chance. They are the result of planned and systematic activities, prevented measures and precautions taken to ensure that the quality of coffee attained and maintained day after day. This is the meaning of quality assurance (Prodolliet, 2005). The quality of coffee can be predetermined by the genotype, the climatic conditions and the soil characteristics of the area in which it is grown. As a whole, a quality assurance program has to be implemented by all the key players of the coffee production to consumer chain to achieve the common goal: quality and as a consequence, consumer satisfaction. Hence, quality assurance can be described from the level of a soluble coffee manufacturer, focusing on the main controls carried out from the reception of the raw material up to the release of the finished packed product.

Definition of terminology according to ECX QUALITY OPERATIONS MANUAL, 2010

Acidity

It is the sensation of dryness that the coffee produces under the edges of your tongue and on the back of your palate. Acidity is often described as "brightness" when favourable or "sour" when unfavourable. The role that acidity plays in coffee is not unlike its role as related to the flavour of wine. It provides a sharp, bright, vibrant quality. Without sufficient acidity, the coffee will tend to taste flat. Acidity should not be confused with sour, which is an unpleasant, negative flavour characteristic (CLU, 2007).

Flavour

This indicates fragrance of the liquor either by direct inhaling of the vapours arising from the cup or nasal perception of the volatile substance evolving in the mouth. Acidity, aroma and body are all components of flavour. The flavour obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee (more than 800 in the roasted coffee). Assessment of measurement of the composition in 800 aromatic compounds present in roasted coffee is not a viable method to assess coffee organoleptic quality, development of indirect predictors of coffee organoleptic quality is underway (Leroy *et al*., 2006) though it was not the objective of this study. These predictors include quantification of chemical compounds present in green coffee (sugars, lipids, proteins, chlorogenic acids, and methylxanthines) via the traditional wet chemistry method and indirect methods like Near Infrared spectra (Bertrand *et al*., 2005). The development of such easy to use and efficient tools should allow large scale phenotyping; a key component towards the implementation of breeding strategies for organoleptic quality in coffee (Bertrand *et al.*, 2005).

Aroma

This is the overall perception of the coffee in your mouth. The aroma of a coffee is responsible for all flavour attributes other than the mouth feel and sweet, salt, bitter, and sour taste attributes that are perceived by the tongue. This is a sensation that is hard to separate from flavour. The aroma contributes to the flavours we discern on our palates. Aroma is perceived by two different mechanisms. It can either be sensed nasally via smelling the coffee through the nose or retro nasally. Retro nasal perception occurs when the coffee is either presents in the mouth or has been swallowed and aromatic volatile compounds drift upward into the nasal passage. Yet, the perception of aroma is dependent upon both the concentration of the compound and its odour threshold. It is probable that a relatively small group of compounds that share both a high concentration and a low odour threshold make up the fragrance we know as coffee aroma. The aroma of coffee is for a large part determined by the roasting of the beans. The four main reactions during the roasting are: Millard reaction; a reaction between nitrogen containing substances (amino acids, proteins, as well as trigonelline and serotonin) and carbohydrates (sugars). Degradation of individual amino acids, particularly, sulphur amino acids, hydroxy-amino acids, and proline.

Body

This is the feeling that the coffee has in your mouth. It is the viscosity, heaviness, thickness, or richness that is perceived on the tongue. Typically, Indonesian coffees possess greater body than South and Central American coffees. Coffees with a heavier body will maintain more of their flavour when diluted with milk (CLU, 2007).

Aftertaste

Aftertaste is defined as the length of positive flavour (taste and aroma) qualities emanating from the back of the palate and remaining after the coffee is expectorated or swallowed. If the aftertaste were short or unpleasant, a lower score would be given.

Balance

How all the various aspects of flavour, aftertaste, acidity and body of the sample work together and complement or contrast to each other is balance. If the sample is lacking in certain aroma or taste attributes or if some attributes are overpowering, the balance score would be reduced.

Sweetness

Sweetness refers to a pleasing fullness of flavour as well as any obvious sweetness and its perception is the result of the presence of certain carbohydrates. The opposite of sweetness in this context is sour, astringency or "green" flavours. This quality may not be directly perceived as in sucrose-laden products such as soft drinks, but will affect other flavour attributes. 2 points are awarded for each cup displaying this attribute for a maximum score of 10 points.

Cup cleanness

Cup cleanness refers to a lack of interfering negative impressions from first ingestion to final aftertaste, a "transparency" of cup. In evaluating this attribute, notice the total flavour experience from the time of the initial ingestion to final swallowing or expectoration. Any non-coffee like tastes or aromas will disqualify an individual cup. 2 points are awarded for each cup displaying the attribute of cup cleanness.

Odour

Whether the coffee was contaminated with bad odour of foreign material or not.

Uniformity

Uniformity refers to consistency of flavour of the different cups of the sample tasted. If the cups taste different, the rating of this aspect would not be as high. 2 points are awarded for each cup displaying this attribute, with a maximum of 10 points if all 5 cups are the same.

Overall

The "overall" scoring aspect is meant to reflect the holistically integrated rating of the sample as perceived by the individual panellist. A sample with many highly pleasant aspects, but not quite "measuring up" would receive a lower rating. A coffee that met expectations as to its character and reflected particular origin flavour qualities would receive a high score. An exemplary example of preferred characteristics not fully reflected in the individual score of the individual attributes might receive an even higher score. This is the step where the panellists make their personal appraisal.

Bean size

This is defined as grade from a commercial point of view, is an important factor since price is related to coffee grade (small beans of the same variety can bring lower prices). Roasting should ideally be carried out with beans of the same size. When uneven sized beans are roasted, the smallest tend to burn and the largest tend to be under-roasted, affecting the visual appearance of the beans and, more importantly, the cup quality (ECX, 2009).

Defects

This are anything divergent from regular nicked sound green beans expected in a coffee lot and classified them into five categories (ISO, 1993; Wintgens, 2004). These are:

- Field damaged bean or processed damaged bean (related to the coffee tree, the environment, attack by pests and diseases, and crop management).
- Harvest-damaged beans or processed damaged beans (caused by stress due to water or nutrient deficiencies, inadequate cultivation or harvesting practices, unsatisfactory primary processing).
- Defects occurring during processing (process damaged beans during like pulping, washing, drying, hulling, cleaning, etc.).
- Defects occurring during storage and
- Defects originated from coffee fruit (due to poor cleaning operation following de-husking and de-hulling).

These are the most important criterion in evaluation of green coffee, as their presences alter the final cup quality by generating off flavour.

Defects can be primary or secondary.

Primary Defect: This includes: full black, full sour, fungus attacked, foreign matter, sever insect damaged, dried cherry, wanza seed and earth.

Secondary Defect: This includes: partial black, partial sour, floater, immature, withered, shell, slightly insect damaged, broken, foxy, spongy/under dried, white, soiled, parchment, hull/husk, mixed, stinker, faded, coated, light, and starved.

Preliminary Assessment

Raw and cup analysis in order to differentiate between potential specialty coffee and commercial coffee.

Total raw value

The summation of physical quality attributes according to the types of processed coffee in the treatment; accounting 40% of the total coffee quality.

Specialty Coffee

Coffees that are grown in special and ideal climates, and are distinctive because of their full cup taste and little to no defects. The unique flavours and tastes are a result of the special characteristics and composition of the soils in which the bush is grown and hence from which the coffee is produced.

Washed Coffee

Green coffee prepared by wet processing of the fruit.

Unwashed Coffee

Green coffee prepared by dry processing of the fruit.

3. MATERIALS AND METHODS

3.1. Study site description

The experiment was conducted at the Jimma University, College of Agriculture and Veterinary Medicine (herein after the JUCAVM) in 2014. The area is located at 7^0 46‘N latitude and 36^o E longitudes. Its average elevation above sea level is about 1753 m with a mean total annual rainfall amounting to 1580 mm. The temperature of Jimma Zone varies from 8-28^0C. The annual average temperature is 20^0C (Jimma Meteorological Weather Station Data Summary Sheet, 2014).

According to the classification based on agro-climatic and thermal zones of the country, the area lies in sub-moist agro-ecological Zone Jimma Meteorological Weather Station Data Summary Sheet, 2014). The soil type of the study area where pots were filled is *Eutric Nitisol* which is highly suitable for coffee production (JARC, 2014).

3.2. Experimental materials, treatments and Design

The already established three years old Arabica coffee trees possessing spacing of 1m and 2m between rows were used for sampling. Three coffee varieties (744, 7440 and 74110) and four shade levels 0% shade (open sun), 30% shade, 50% shade and 70% shade levels were used as an experimental treatment. The coffee varieties have different bean size and average to good cup quality which are commercially acceptable quality (Behailu *et al.*, 2008). Besides, the varieties were selected for their wide range of adaptability, better quality and yield performance (Appendix table 2). These varieties are among the top ten leading types in terms of amount of seed distribution to different coffee producing areas of Ethiopia (Taye, 2012) and adaptable to wide range of climate from mid to high land area. The experimental treatments were arranged in a split-plot design considering shade levels as main plot and variety as sub-plot. The four shade levels and three coffee varieties gave a total of 12 treatment combinations having three replications making the total number of experimental units 36.

3.3. Experimental Procedures

The experiment was conducted at horticulture research site having a 40.5 m × 20 m artificial shade allowing different light regimes which was covered on all sides with a single-layer of nylon screens, supported by wooden frame and rafters The nylon screens were installed horizontally at a vertical height of two meter above the ground.

During days of transplanting, all the coffee seedlings were fertilized with 25 g of Triple Super Phosphate (TSP) per pot following the recommendation of the (JARC, 1996). Then 160 kg Urea fertilizer per ha was applied every four months, by dividing it into three applications in the months of August, December and April during the early growth stage of the seedlings. The fertilizers were evenly spread over a zone beginning 10-15 cm from the trunk of the seedlings and extending to the tip of the lateral branches (leaf drip line).

Uniformly grown three years old potted coffee trees having (60 x 60 cm) dimension possessing were used for sampling. A distance of 0.5 m and 1 m was maintained between unit plot and blocks respectively.

3.4.1. Sampling and sampling methods

- **Harvesting and sorting**

Fully matured red cherries from uniformly grown 3 years old coffee berry disease resistant varieties (744, 7440 and 74110) were hand harvested 5kg per sample were collected during main harvesting season of year 2014 for each varieties. Immature coffee berries and foreign matters were sorted out. Each variety was sub-divided into their respective treatments and sun dried.

3.4.2. Sun drying

A total of 36 samples were prepared as sun dried/natural. During preparation selectively picked red cherries. The red cherries labelled and properly dried on raised compartmented mesh wire drying table (0.8m above the ground) and samples were regularly turned to maintain uniform drying. Finally, after three weeks of drying, the dried coffee cherries (at 11.5% moisture content) were separately labelled and packed.

3.4.3. Hulling (de-husking)

Using hulling machine from JUCAVM, dried beans were hulled, cleaned and finally 100 gm clean green bean obtained per sample and used as dry processed Arabica (DPA) (ISO, 2004).

3.4.4. Labelling and packing

Each coffee sample was prepared from each treatment and separately labelled. The samples were packed and taken to ECX Coffee Quality Inspection and Grading centre for quality analysis.

3.4.5. Coding

The samples separately coded in the coding room according to the standard procedure employed in the Coffee quality Inspection and Grading Centre to avoid individual biasness of the panel, including the researcher.

3.5. Data Collection

All quality evaluation attributes including physical attributes (primary defects, secondary defects, hundred bean weight and odour) and cup quality attribute factors (cup cleanness, acidity, body and flavour) were considered as per the standard recommendation (QSAE, 2000).

3.5.1. Bean size

Bean size was determined using a bean measuring calliper taking 80 beans per each sample and the average value was considered for analysis.

3.5.2. Hundred bean weight

Weight of 100 beans for each sample was measured using sensitive weight scale. The weight was measured and recorded in gram.

3.5.3. Raw/ physical quality analysis

During raw quality analysis, 100g of green bean was used for each sample and their defects (primary and secondary defects) and odour were measured according to the Ethiopian quality standard (QSAE, 2000) and these data were evaluated based on green coffee reference chart which is a published Working Draft 4467: 2000 by QSAE identical with ISO 10470: 2004. They were rated on a scale from 0 to 15 and odour got a score from 0 to 10.

Defects were manually separated and counted according to their type. Each coffee sample was taken using digital bean balance. The beans were graded size using standard screens having different screen size, with round holes as defined in the International Organization for Standards (ISO) (2000). Besides, size determination was determined using calliper and defect counts were been made for dry processed green coffee beans by internationally fixed standard set (CLU, 2007). The beans were visually inspected and evaluated for raw quality (accounting for 40% of the total coffee quality).

3.5.4. Roasting analysis

The roaster machine with six cylinders (Probat BRZ6, welke, Von Gimborn Gmbhan Co. KG) was first heated to about 160^0C-200^0C. About 100gm coffee beans sample per each treatment per each replication were put into the roasting cylinder and roasted for an average of 7-8 minutes to medium roast at ECX laboratory located at Jimma town. The medium roast coffee was tipped out into a cooling tray and allowed to cool down (on an average for four minutes) rapidly by blowing cold air through it. When the roast was cool it was blown to remove the loose silver skins before grinding.

3.5.5. Grinding

The coffee samples were ground to medium size using electrical grinder adjusted to 1.5 sizes and the grinder was cleaned well after each sample. 100 grams of bean from each samples of coffee before and after roast measured and the data recorded using gradated cylinder. The volume difference after roast recorded in g/cm^3.

3.5.6. Brew preparation

Eight gram of coffee powder was put into each cup having 250ml of capacity (5 cups per sample unit). Fresh boiled water were poured onto the ground coffee up to about half size of the cup, followed by stirring the content to ensure the homogeneity of the mixture. Then, the cups were filled to the full size and left to settle. After three minutes, the floaters were skimmed and ready for cup tasting.

3.5.7. Preliminary cup quality analysis / liquor analysis

For each treatment sample using the round soup spoon raise 6 to 8 cc of liquid to just in front of the mouth and forcefully slurp the liquid. By briskly aspiring, the coffee in this way spread evenly over the entire surface of the tongue. A team of trained, experienced and internationally certified Q grader cuppers made this. In this case, five expertises including the researcher participated in a panel for cupping to evaluate the aroma and taste characteristics of each sample of the brew involving olfaction, gestation, and mouth feel sensation. Average result of cuppers used for analysis.

Cup acidity: During cup acidity analysis, evaluated as, pointed (15%), and moderately pointed (12 %), medium (9 %), light (6 %) or lacking (3 %) and the result were recorded accordingly.

Body: Cup body evaluated as, full (15 %), moderately full (12 %), medium (9 %), light (6 %), and thin (3 %). The result recorded accordingly.

Flavour: The flavour, the overall test of the brew evaluated and recorded as good (15%), fairly good (12%), average (9%), fair (6 %) and weak (3%).

Cup cleanness: A spoonful of the brew was sucked with air into mouth of a taster and held at the back of the tongue between the tongue and the roof of the mouth where the tasting glands are located. It was held in the mouth and moved around for few (7-10) seconds for cup quality evaluation, which involved taste for cleanness of the cup (defective cups including foul, musty, earthy, chemical, etc.).

Assessment of cup quality attributes were carried out at Ethiopian Commodity Exchange (ECX) coffee liquoring laboratory located at Jimma town by a team (three cuppers) of experienced and certified professional panellists. Each panellist gave his/her independent judgment for each sample unit of the treatment. Finally, the average results of all panellists were used for data analysis.

Accordingly, the cup quality evaluation consisted of raw/physical quality analysis (40%) and liquor (60%) (Appendix Table 4 and 5). Raw value was evaluated as primary defects, secondary defects and odour. Whereas liquor was also evaluated as acidity, body, flavour and cup cleanness. The sum of both cup value and raw value resulted in a total preliminary score between 0 and 100. It is based on this total quality value that the sampled coffee was classified into different grades (Appendix Table 7).

3.5.7. Speciality quality analysis

Based on the assessment of the preliminary analysis, coffee samples that fall under Grade 1-3 is called specialty coffee and further cup quality assessment were carried out based on the specialty coffee cupping form focusing on the following cup quality attributes aroma, flavor, acidity, body, uniformity, cup cleanness, overall preference, aftertaste, balance and sweetness and were rated on a scale from 0 to 10. The sum of all these all cup quality attributes gave a total cup specialty points ranging from 0 to 100. Based on the this cupping result new specialty grade have been given for the coffee samples as follows: Specialty 1 (Q1) $\geq$ 85 points , Specialty 2(Q2) $\geq$80 points and commercial (Grade 3) $<$ 80 points.

3.6. Data Analysis

All the data were examined for homogeneity of variance and normality and were found to have normal distributions. Then, the data were subjected to analysis of variance using statistical software package SAS 9.1.3. The differences between treatment means were compared using least significance difference (LSD) test at 5% level of significance.

4. RESULTS AND DISCUSSION

4.1. Bean size (mm)

The result of analysis of variance revealed that bean size of Arabica coffee was very highly significantly ($P \leq 0.001$) influenced by the interaction effect of variety and shade level (Appendix Table 1). As indicated in Table 2, variety 744 showed consistent increment in bean size as the shade level increased from 0% to 70%. However, such type of consistent increment was not observed in bean size across 7440 and 74110 coffee varieties under increased shade levels from 0% to 70%. Variety 74110 had small bean size under 70% shade level although the difference is not statistically significant with 50%, 30% and 0% shade levels. Accordingly, variety 744 was found to be the biggest in bean size (bean diameter= 6.69 mm) under **7**0% shade as compared to the two varieties under all shade levels (Table 1).

On the other hand, coffee beans collected from open sun had relatively the smallest bean size which was statistically identical with beans collected from 30% and 50% but it is statistically significant with 70% shade level. Growing coffee under shade improved the size of the coffee beans by 4% than coffee beans which were harvested from open sun according to the reports of Takele (2012). The variation in bean size in the present study might be due to the effects of shade which might have influence on bean filling during maturation than coffee growing in the open sun. Aske *et al*. (2009) demonstrated that the proportion of small beans significantly decreased with increasing shade level in Timana, Southern Colombia, which is in confirmation with the present findings.

According to the findings of Adugna and Paul (2011), bean weight and size assessment made on harvested coffee beans indicated that beans developed under shaded condition were heavier and larger in size and had better liquor taste than those developed under open sun. Another study from Costa Rica confirmed that fruit weight and bean size increased significantly when shade intensity was increased from 0% to 80% under different coffee varieties (Avelino *et al*., 2007).

Bean size, which is usually determined by screening/using calliper, is of particular importance to roasters since bean of the same size would be expected to roast uniformly. The current study is in agreement with the reports of JARC (1996) who identified the variety 74110 by its small sized beans while the variety 744 by its large sized beans although the agricultural management system including shade level is not specified. Besides, Yigzaw (2006); Bertrand *et al*. (2006) described that bean size can be influenced by both botanical variety and environmental growth circumstances.

4.2. Hundred Bean Weight (gm)

The interaction effect of variety and shade levels was highly significantly ($P \leq 0.001$) influenced hundred bean weight of Arabica coffee (Appendix Table 1). As can be seen from the mean values across all varieties, there is a general increase in bean weight as the shade level increased from 0% to 70%. Accordingly, all the three varieties scored relatively the maximum bean weight under 70% shade although the difference is not statistically significant. Likewise, all the three varietal score was relatively less heavier under 0% shade as compared to those under 30%, 50% and 70% shade although this difference is not statistically significant (Table 1).

The variation in bean weights obtained in this study for the different coffee varieties and shade levels is in accordance with the idea of the previous authors who reported that Arabica coffee varieties were diverse in average weight of hundred bean with the values ranging between 9.2 gm and 18.2 gm in various management systems.

Moreover, the variation in bean weight obtained in this study can also be explained in terms of the different bean sizes of the different coffee varieties included in the current study. The result, therefore, indicates the existing heterogeneity among coffee genotypes for bean characteristics. Similar with this study, variety 74110 was reported to have small bean size while 744 characterized by bigger size (JARC, 1996). Therefore, the present findings support the idea of Cannell (1985) who confirmed as if coffee grown under open sun had a decreased bean weight.

Earlier study of Ebisa (2014) from Manasibu district, West Ethiopia also observed relatively higher coffee weight (21.5 g/100 beans) in shaded zone than unshaded zone of coffee farms although the difference was not statistically significant. The fact that increased shade levels resulted in heavier and larger coffee beans was mainly caused by its effect on temperature and the duration of the ripening period. Muschler (2001), found comparable results, in that coffee bean size significantly and consistently increased even with increasing shade levels from 30 to 55%.

Table 1. Interaction effects of varieties and shade levels on bean size and hundred bean weight of Arabica coffee at Jimma, 2014.

Shade levels	Varieties	Bean size (mm)	Hundred bean weight (gm)
70% shade	744	6.69a	16.06a
	7440	6.41b	15.30abc
	74110	6.03f	15.40ab
50% shade	744	6.28bcd	14.37abc
	7440	6.33bc	14.73abc
	74110	6.19cdef	14.97abc
30% shade	744	6.09ef	13.87bc
	7440	6.13def	14.30abc
	74110	6.19cdef	13.50c
0% shade	744	6.07f	13.77bc
	7440	6.28bcd	10.57d
	74110	6.24bcde	9.10d
LSD (0.05)		0.17	1.80
CV (%)		1.64	7.74

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.3. Preliminary Total Quality

Results of the present study showed that there were significant differences in some coffee bean qualities such as primary defects, secondary defects, total raw quality, flavour, total preliminary cup quality and total preliminary quality attributes due to the coffee varieties and shade levels

(Appendix Table 1). But odour, cup cleanness, acidity and body were found to be non-significant due to the main effects of varieties and shade levels as well as their interaction.

4.3.1. Preliminary Raw Quality Analysis

4.3.1.1. Primary defects

Primary defects of Arabica coffee was significantly ($P \leq 0.05$) influenced by the main effect of varieties but not by the main effects of shade levels and interaction (Appendix Table 1). Defects are anything divergent from regular nicked sound green beans expected in a coffee lot. variety 744 and 74110 examined in this investigation showed different results in their primary defects (Table 2).

Coffee varieties differ widely in their primary defects and the present finding is most likely associated with cleaning operation following de-husking and de-hulling, storage, attack by pests and diseases, inappropriate drying conditions, etc. The present finding disagrees with the findings of JARC (1996) who found a less score of primary defects from variety 744. This might be due to conditions related to drying and operations related to de-husking and de-hulling.

Table 2. Primary defects of Arabica coffee under various varietal treatments at Jimma, 2014.

Treatments	Primary defects
Variety	
744	14.50a
7440	13.50ab
74110	12.75b
LSD (0.05)	1.15
CV (%)	9.74

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in the column do not differ significantly at 5% P level according to the LSD test.

4.3.1.2. Secondary Defects

Secondary defects of Arabica coffee was highly significantly ($P \leq 0.001$) influenced by the interaction effect of variety and shade levels (Appendix Table 1). Variety 744 had the highest secondary defects (15) when it is exposed under open sun while the score was lower when the same variety was exposed under 30%, 50% and 70% shade level. Secondary defects for variety 7440 was reduced when shade levels are in increased trend but similar results were registered under 0 and 30% and 50% and 70% shade levels. The highest score of secondary defects for variety 74110 was registered under 50% shade and the minimum score was under open sun for the same variety. Generally the proportion of secondary defects for variety 744 and 7440 get reduced as the shade level gets increased (Table 4).

The present finding agrees with the study conducted in Uganda which pointed out that coffee grown under 66% shade promoted slower and more balanced filling and uniform ripening of berries, thus yielding a reduced primary and secondary defects as compared to the one which were grown under 25% shade level (Peter, 1997).

The higher proportion of secondary defects for the open sun treatments cannot be easily explained with the present data. Although Muschler (2001) showed that shading reduced the number of rejected fruits, the fruit types he rejected most likely resulted from pest and disease pressures and not directly from shading. However, the fact that increased shade levels resulted in reduced primary and secondary defects in the present study is mainly due to the fact that shade has effect in reducing the extremes of sunlight intensity and temperature.

4.3.1.3. Odour

Both the main effects of varieties and shade levels as well as their interaction were found to be non-significant ($P > 0.05$) in affecting the odour of Arabica coffee (Appendix Table 1). Odour tells us whether the coffee was contaminated with bad odour of foreign material or not. Due to the fact that ripe red cherries were selectively picked and sorted from other immature, diseased, insect damaged and other foreign materials and that is why no variations were observed both statistically and numerically.

Table 3. Main effects of varieties and shade levels on odour of Arabica coffee at Jimma, 2014.

		Odour
Varieties	744	10
	7440	10
	74110	10
	LSD (0.05)	ns
Shade levels	70% shade	10
	50% shade	10
	30% shade	10
	0% shade	10
	LSD (0.05)	ns
	CV (%)	0

LSD = least significant difference; CV = coefficient of variation; ns= non-significant

4.3.1.4. Total raw quality

The analysis of variance in the two way interaction effects presented in Table 4 among coffee varieties and shade levels showed highly significant ($P \leq 0.01$) variation on total raw quality of Arabica coffee (Appendix Table 1). Variety 744 scored the highest mean total raw quality value (40) under 70% shade level while the score was similar under 0%, 30% and 50% shade level for the same variety. An increment was observed in mean total raw quality for variety 7440 when its shade level increased from 0 to 30% but it remained constant under 30%, 50% and 70% shade level. On the other hand, variety 74110 showed non-consistent increment under various shade levels (Table 4). These could be due to the combined effects of varieties and shade levels in that variety 744 was identified by its best variety in its some of the attributes like primary and secondary defects (JARC, 1996).

As cited by Adugna and Paul (2011) from Kasai (2008), many of the physiological processes of plants are temperature dependent in which under high temperature (open sun) crops experienced great difficulty in maintaining photosynthetic activities and growth. Coffee is exceptionally sensitive to leaf temperature. For the coffee plants grown in direct sun light, increased air temperature above the optimum level resulted in subsequent lowering of stomatal conductance which in turn imposed a large limitation on the rate of CO_2 assimilation thereby affecting the total raw qualities of coffee.

Table 4. Interaction effects of varieties and shade levels on secondary defects and total raw quality of Arabica coffee at Jimma, 2014.

Shade levels	Varieties	Secondary defects	Total raw quality
70% shade	744	12.00c	40a
	7440	12.00c	39ab
	74110	14.00b	37bcd
50% shade	744	12.00c	37bcd
	7440	12.00c	39ab
	74110	15.00a	39ab
30% shade	744	12.00c	36cde
	7440	15.00a	38abc
	74110	14.00b	37bcd
0% shade	744	15.00a	36cde
	7440	15.00a	35de
	74110	12.00c	34e
LSD (0.05)		0.84	2.67
CV (%)		3.66	4.25

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.3.2. Preliminary Cup Quality Analysis

4.3.2.1. Cup cleanness

Both the main effects of varieties and shade levels as well as their interaction were found to be non-significant ($P > 0.05$) in affecting cup cleanness of Arabica coffee in their preliminary quality analysis (Appendix Table 1). This quality attribute scored similar result throughout all treatments (Table 5). This is probably due to ripe red cherries were selectively picked and sorted from other immature, diseased, insect damaged and dry berries as well as other foreign materials were properly selected and that is why no variations were observed both statistically and numerically.

4.3.2.2. Acidity

In this study neither the main effects nor their interaction was found to be significant (P > 0.05) in affecting acidity of Arabica coffee in their preliminary quality analysis (Appendix Table 1). This shows that all varieties and shade levels studied in this experiment were found to be equally important for acidity.

4.3.2.3. Body

The influence of coffee varieties, shade levels and their interaction was found to be statistically non-significant (P > 0.05) in affecting body of Arabica coffee in their preliminary quality analysis (Appendix Table 1). This shows that all varieties and shade levels studied in this experiment were found to be equally important for body.

Table 5. Main effects of varieties and shade levels on cup cleanness, acidity and body of Arabica coffee at Jimma, 2014 (Preliminary quality analysis)

		Cup cleanness	Acidity	Body
Varieties	744	15	12	10.75
	7440	15	12	10.75
	74110	15	12	10.25
	LSD (0.05)	ns	ns	ns
Shade levels	70% shade	15	12	10.67
	50% shade	15	12	10.33
	30% shade	15	12	10.00
	0% shade	15	12	11.33
	LSD (0.05)	ns	ns	ns
	CV (%)	0	0	14.17

LSD = least significant difference; CV = coefficient of variation; ns= non-significant

4.3.2.4. Flavour

Cup quality evaluation revealed highly significant ($P \leq 0.001$) variations on interaction effects of varieties and shade levels on flavour of Arabica coffee in their preliminary quality analysis as presented in Appendix Table 1. The flavour obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee. As indicated in Table 6, variety 744 exhibited an increase in the flavour as the shade level increased from 0% (open sun) to 50% but scored a reduced value as the shade level is further increased to 70%. Similar trend was observed in variety 7440. Regarding variety 74110, it was similar in its flavour under shade levels 0% and 70% and 30% and 50% (Table 6). This result is possibly found due to the inherent variability that exists in the respective varieties.

Though the different quality parameters of coffee are under the influence of various factors like environmental and management factors, some coffee varieties were found to have more potential than other varieties for flavour. Muschler (2001) reported that various coffee varieties along with various levels of shade can have significant effect not only on flavour but also on other associated quality attributes. On the other hand, studies have also indicated that the chemical base and cup qualities of coffee depend mainly on the area grown and management conditions regardless of the varieties of the coffee (Shitaye *et al*., 2014).

4.3.2.5. Preliminary Total Cup Quality

The analysis of variance in the two way interaction effects among coffee varieties and shade levels showed the presence of very highly significant ($P \leq 0.05$) variation in total cup quality of Arabica coffee (Appendix Table 1). Preliminary total cup quality exhibited non-consistent trend across the two coffee varieties (7440 and 74110) subjected to various shade levels. However, coffee varieties 744 exhibited a consistent increment in its preliminary total cup quality as the shade level increased from 0% to 70% (Table 6).

According to the findings of Adugna and Paul (2011), beans developed under shaded condition had better liquor taste than those developed under open sunlight regardless of the shade levels. This is probably due to the fact that shade is very much essential to reduce the intensity of sunlight and temperature and due to the fact that adequate shade improves soil fertility by returning large amounts of leaf litter to the underneath soil which on the other hand have its own contribution on bean liquor quality. Indeed, it is not only shade but also the elevation of the area which is known to influence coffee cup quality. It is easy to imagine that shaded coffee at lower altitudes may have the largest potential for impact on cup quality (Soto-Pinto *et al*., 2000). This is because of the microclimatic changes that shade provides for coffee. In low-growing regions, lowering the average temperature (with shade) can mimic higher altitude conditions (sometimes dropping temperatures as much as 4°C), thus improving the cup quality (Avelino *et al*., 2007; Vaast *et al*., 2005).

Multiple studies have found that the acidity and body of brewed low-altitude coffee was improved by shading (Muschler 2001; Vaast *et al*. 2005; Steiman *et al*., 2008). They suggested that this higher growing temperature produced a more uniform ripening of berries, which led to the better quality cup with shading. Related to this, there is a possibility that shade at higher elevations could be detrimental to qualify if the temperature range drops below what is ideal for coffee, but shade trees can also provide a buffer from frosts so this will depend on the individual microclimate.

4.3.3. Preliminary total quality (Raw total + Cup total)

The analysis of variance in the two way interaction effects among coffee varieties and shade levels showed the presence of very highly significant ($P \leq 0.01$) variation in its preliminary total of Arabica coffee (Appendix Table 1). As indicated in Table 6, variety 744 exhibited an increase in the total preliminary total as the shade level increased from 0% (open sun) to 50% but scored a reduced value as the shade level is further increased to 70%. Like that of variety 744, a similar trend was observed in variety 74110. However, consistent increments were observed in preliminary total value in variety 7440 as the shade increased from 0% to 70%.

The variation of result obtained in the total quality of coffee in the present study might be due to the influence of shade on environmental conditions at different degree, because of the different nature of the varieties and shade levels at the Jimma agro-ecology.

Some studies have not found an increase in total raw and cup quality in shade-growing conditions. Studies conducted in Hawaii determined that coffee shaded artificially and under tree cover had no difference in raw quality from sun-grown coffee (Moreno *et al*., 1995). One study even found that shade-grown coffee had lower cup quality in very wet conditions (Vaast *et al*. 2005). Hence, from those investigations it is possible to conclude that coffee quality is the result of not only shade levels and varieties only but also other environmental conditions like altitude and others.

Table 6. Interaction effects of varieties and shade levels on flavour, preliminary total cup quality and preliminary total of Arabica coffee at Jimma, 2014.

Shade levels	Varieties	Flavour	Preliminary total cup quality	Preliminary total quality
70% shade	744	10bc	47bc	85.67abc
	7440	11bc	50ab	87.67a
	74110	9c	46c	83.00cd
50% shade	744	15a	53a	88.00a
	7440	12b	49bc	86.67ab
	74110	12b	49bc	86.00abc
30% shade	744	10bc	48bc	84.00bcd
	7440	12b	48bc	86.00abc
	74110	9c	46c	83.00cd
0% shade	744	9c	47bc	83.00cd
	7440	11bc	50ab	83.67bcd
	74110	9c	47bc	81.00d
LSD (0.05)		2.23	3.37	3.17
CV (%)		13.16	4.21	1.99

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.4. Speciality cup Quality

The result of the present study revealed that most of the speciality quality parameters were found to be significantly affected by the interaction effects of coffee varieties and shade levels except acidity and body.

4.4.1. Acidity

Acidity is a primary test sensation, and a high acidic coffee has pointed sharp pleasing flavour. In the present study, neither the main effects of varieties and shade levels nor their interaction was found to be significant ($P > 0.05$) in affecting acidity of Arabica coffee (Appendix Table 2). This shows that all varieties and shade levels studied in this experiment were found to be equally important for acidity in its speciality analysis.

4.4.2. Body

Body implies to impression of consistency given by coffee brew. Based on the results of the present study, the influence of coffee varieties, shade levels and their interaction was found to be statistically non-significant (P > 0.05) in affecting body of Arabica coffee (Appendix Table 2). This shows that all varieties and shade levels studied in this experiment were found to be equally important for body.

Table 7. Main effects of varieties and shade levels on acidity and body of Arabica coffee at Jimma, 2014.

		Acidity	Body
Varieties	744	7.48	7.58
	7440	7.36	7.58
	74110	7.46	7.61
	LSD (0.05)	ns	ns
Shade levels	70% shade	7.42	7.53
	50% shade	7.59	7.69
	30% shade	7.37	7.61
	0% shade	7.37	7.53
	LSD (0.05)	ns	ns
	CV (%)	5.29	1.98

LSD = least significant difference; CV = coefficient of variation; ns= non-significant

4.4.3. Flavour

Cup quality evaluation revealed highly significant (P≤ 0.01) variations on interaction effects of varieties and shade levels on flavour as presented in Appendix Table 2. A non-consistent trend in flavour was observed across all the three coffee varieties subjected to various shade levels. However, the strongest flavour (8.33) was noticed from the variety 744 under 50% shade level (Table 8). This result is possibly found due to the inherent variability that exists in the respective varieties.

Though the different quality parameters of coffee are under the influence of various factors like environmental and management factors, some coffee varieties were found to have more potential than other varieties for flavour. Muschler (2001) reported that various coffee varieties along with various levels of shade can have significant effect not only on flavour but also on other associated quality attributes. On the other hand, studies have also indicated that the chemical base and cup qualities of coffee depend mainly on the area grown and management conditions regardless of the varieties of the coffee (Shitaye *et al*., 2014). This finding agrees with Takele (2012) who reported that shade significantly affected beverage quality of coffee.

4.4.4. Aroma

The results of analysis of variance revealed that aroma of Arabica coffee was very highly significantly ($P \leq 0.001$) influenced by the interaction effect of variety and shade levels (Appendix Table 2). The aromatic aspects include fragrance (defined as the smell of the ground coffee when still dry) and aroma (the smell of the coffee when infused with hot water).

Aroma of Arabica coffee exhibited non-consistent trend across all the three coffee varieties subjected to various shade levels. The mean comparison among the coffee varieties showed that variety 744 and 7440 scored strong to medium aroma at 50% shade level. Accordingly, the highest/strongest mean aroma value (9.08) was noticed from variety 744 under 50% shade level followed by variety 7440 under the same shade level. All the remaining varieties had similar results under all shade levels (Table 8).

This result is possibly found due to the inherent variability that exists in the respective varieties. The variety 74110 is identified by JARC (1996) with its small sized beans and commercially accepted quality by its aroma, while the variety 744 revealed by its large sized beans and commercially accepted quality by its aroma. Studies have also indicated that the chemical base and cup qualities like aroma of Arabica coffee depend mainly on the management conditions such as shade and environment grown (mainly altitude) (Cannell, 1985).

4.4.5. Aftertaste

The results of analysis of variance revealed that the interaction effect of variety and shade levels was highly significantly ($P \leq 0.01$) influenced aftertaste of Arabica coffee (Appendix Table 2).

Aftertaste is defined as the length of positive flavour (taste and aroma) qualities originating from the back of the palate and remaining after the coffee is swallowed. If the aftertaste were short or unpleasant, a lower score would be given.

The mean comparison among the coffee varieties showed that aftertaste of Arabica coffee exhibited non-consistent trend across all the three coffee varieties subjected to various shade levels. However, the highest mean value of aftertaste (8.25) was noticed from variety 744 under 50% shade level. All the remaining varieties had similar results under all shade levels (Table 8). One study found that aftertaste was more likely linked to shaded growth conditions (Lara-Estrada and Philippe, 2006). Few studies have even concluded that sun-grown coffee registered lower values of aftertaste as compared to the one grown under shade (Avelino *et al*. 2007; Vaast *et al*. 2005). In addition to this, the inherent variability that exists in the respective varieties might also be the possible justifications for the variations.

Table 8. Interaction effects of varieties and shade levels on flavour, aroma and aftertaste of Arabica coffee at Jimma, 2014.

Shade levels	Varieties	Flavour	Aroma	Aftertaste
70% shade	744	7.50b	7.42cd	7.58b
	7440	7.25bc	7.50c	7.42bc
	74110	7.50b	7.25cd	7.33bc
50% shade	744	8.33a	9.08a	8.25a
	7440	7.67b	8.08b	7.67b
	74110	7.42bc	7.33cd	7.50b
30% shade	744	7.50b	7.25cd	7.25bc
	7440	7.33bc	7.25cd	7.25bc
	74110	7.25bc	7.33cd	7.33bc
0% shade	744	7.25bc	7.50c	7.33bc
	7440	7.33bc	7.08cd	7.25bc
	74110	7.00c	6.75d	6.92c
LSD (0.05)		0.49	0.56	0.53
CV (%)		3.96	4.44	4.27

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.4.6. Balance

The results of analysis of variance revealed that balance of Arabica coffee was highly significantly ($P \leq 0.01$) influenced by the interaction effect of variety and shade levels (Appendix Table 2). How all the various aspects of flavour, aftertaste, acidity and body of the sample work together and complement or contrast to each other is termed as balance. If the sample is lacking in certain aroma or taste attributes or if some attributes are overpowering, the balance score would be reduced.

The mean comparison among the coffee varieties showed that balance of Arabica coffee exhibited non-consistent trend across the two coffee varieties (744 and 7440) subjected to all shade levels. The trend for variety 74110 was consistent increment although statistically non-significant. However, relatively the highest mean value of balance (8.17) was noticed from variety 744 under 50% shade level. All the remaining varieties had similar results under all shade levels (Table 9). Like that of the results of aroma and flavour above, this result is possibly found due to the inherent variability that exists within the varieties. The result agreed with Agwanda (2003) and Yigzaw (2006) indicated that balance can be considered as a selection criterion for the genetic improvement of overall liquor quality and there was variation in their balance among genotypes of Arabica coffee. Subedi (2010) and Tsegaye *et al*. (2014) also reported that dry processed (natural) coffee has a full balance and natural sweetness of the beans.

4.4.7. Overall cup preference

On the basis of the cup quality evaluation, the overall cup preference of Arabica coffee was significantly ($P \leq 0.05$) influenced by the interaction effect of variety and shade levels (Appendix Table 2). The “overall preference” scoring aspect is meant to reflect the holistically integrated rating of the sample as perceived by the individual panellist. A sample with many highly pleasant aspects, but not quite “measuring up” would receive a lower rating. A coffee that met expectations to its character and reflected particular origin flavour qualities would receive a high score.

The mean comparison among the coffee varieties showed that except coffee variety 744 under 50% shade level which registered the highest mean value for overall cup preference (8.17), all the remaining coffee varieties scored similar results under all shade levels (Table 9). This implies that the best overall preference for Arabica coffee was recorded by variety 744 under 50% shade level. Studies conducted in Costa Rica indicated that as shade level increased from 43 to 72%, an increase in overall preference has been observed along with its other cup quality evaluations. The primary reason reported was, it might be the result of delayed ripening due to the shade and its microclimatic effects. It is likely that the same factors were responsible for the higher quality particularly of shaded coffee in the present study (Muschler, 2001).

4.4.8. Total speciality cup quality

The total specialty cup quality involves the evaluation of cup analysis used to determine the quality potential of coffee variety (genotype) to classify the coffee into specialty grades. The result of analysis of variance revealed that the interaction effect of variety and shade levels were highly significantly ($P \leq 0.001$) influenced total speciality cup quality of Arabica coffee (Appendix Table 2). Like that of the total cup quality discussed above, the total speciality cup quality exhibited non-consistent trend across all the three coffee varieties subjected to various shade levels. However, the highest total specialty cup quality mean value (87.41) was noticed from the variety 744 under 50% shade level (Table 9). This result is possibly found due to the inherent variability that exists in the respective varieties and shade management strategies.

The above explanation holds true for the total speciality cup quality in that beans developed under shaded condition had better liquor taste than those developed under open sunlight regardless of the shade levels Adugna and Paul (2011). This is probably due to the fact that shade is very much essential to reduce the intensity of sunlight and temperature and adequate shade also improves soil fertility by returning large amounts of leaf litter to the underneath soil which on the other hand have its own contribution on bean liquor quality.

The variety 74110 is identified by JARC (1996) with its small sized beans and commercially accepted quality, while the variety 744 is revealed by its large sized beans and commercially accepted quality. Yigzaw (2006) reported as if there is a presence of genetic variability among Ethiopian coffee cultivars for bean physical characteristics and cup quality attributes. This statement also supports the findings of Subedi (2010) in that, bean size plays an important role in roasting processes because many consumers associate bean size with quality. However, large beans do not necessarily taste better than smaller one.

The present result agrees with the findings of Peter (1997) who pointed out that an excellent quality coffee can only be obtained through an application of appropriate and scientifically tested practices particularly proper shade management. Similarly, this result is in line with Aske *et al*. (2009) who reported that coffee varieties managed under proper shade level and appropriate field management will have better quality as far as their total physical and cup quality attributes are concerned. Aske *et al*. (2009) also confirmed that if consistent quality control is applied to dry processing, the resulting coffee is highly preferred by the specialty coffee industry.

Table 9. Interaction effects of varieties and shade levels on balance, overall cup preference and total specialty cup quality of Arabica coffee at Jimma, 2014.

Shade levels	Varieties	Balance	Overall cup preference	Total specialty cup quality
70% shade	744	7.50bc	7.50b	82.50bc
	7440	7.33bcde	7.42b	81.75cd
	74110	7.50bc	7.33b	81.92cd
50% shade	744	8.17a	8.17a	87.41a
	7440	7.58bc	7.42b	83.83b
	74110	7.75ab	7.58b	82.58bc
30% shade	744	7.25cde	7.17b	81.33cd
	7440	7.42bcd	7.58b	81.83cd
	74110	7.33bcde	7.50b	81.75cd
0% shade	744	7.33bcde	7.42b	81.75cd
	7440	7.00de	7.25b	80.50d
	74110	6.92e	7.58b	80.58d
LSD (0.05)		0.49	0.47	1.86
CV (%)		3.93	3.76	1.34

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

5. SUMMARY AND CONCLUSIONS

Nowadays, coffee quality is the most appreciated characteristic in the international coffee trade and various investigations have shown how various factors influenced the physical, cup and biochemical characteristics of Arabica coffee. Management practices, including shading, generally influence the physical and cup qualities of coffee beans. In view of this, three varieties of Arabica coffee under four levels of shade were evaluated during the 2014 academic year to examine qualities of Arabica coffee at Jimma. Accordingly, the results of analysis of variance revealed significant differences in combined effects of coffee varieties and shade levels in most of the parameters studied including bean size and hundred bean weights.

The present finding revealed that coffee quality is highly determined by varietal characteristics and shade levels and has shown as if there is variability among the coffee varieties for bean physical characteristics and cup quality. Accordingly, variety 744 was found to be the biggest in its bean size under 70% shade as compared to the two varieties under all shade levels. There is a general increase in bean weight as the shade level increased from 0% to 70%.

The proportion of primary and secondary defects for variety 744 and 7440 get reduced as the shade level gets increased. Odour, cup cleanness, acidity and body were found to be non-significant. Variety 744 scored the highest mean total raw quality value under 70% shade level while the score was similar under 0%, 30% and 50% shade level for the same variety. A non-consistent trend in flavour was observed across all the three coffee varieties subjected to various shade levels. However, the highest mean value for flavour in its preliminary cup analysis was noticed from the variety 744 under 50% shade level.

Total cup quality and total coffee quality exhibited non-consistent trend across all the three coffee varieties subjected to various shade levels. The highest overall total preliminary coffee quality mean value was noticed from the variety 744 under 50% shade level. The present study revealed that most of the speciality quality parameters were found to be significantly affected by the interaction effects of coffee varieties and shade levels except acidity and body. Accordingly, a non-consistent trend in flavour was observed across all the three coffee varieties subjected to various shade levels. However, the highest mean value for flavour was noticed from the variety 744 under 50% shade level.

Aroma was strong to medium in variety 744 and 7440 under 50% shade level. The strongest aroma was noticed from variety 744 under 50% shade level followed by variety 7440 under the same shade level. Aftertaste of Arabica coffee exhibited non-consistent trend across all the three coffee varieties subjected to various shade levels. However, the highest mean value of aftertaste was noticed from variety 744 under 50% shade level. Likewise, balance of Arabica coffee exhibited non-consistent trend across the two coffee varieties (744 and 7440) subjected to various shade levels. The trend for variety 74110 was consistent increment although statistically non-significant. However, the highest mean value of balance was noticed from variety 744 under 50% shade level.

The mean comparison among the coffee varieties showed that except coffee variety 744 under 50% shade level which registered the highest mean value for overall cup preference, all the remaining coffee varieties scored similar results under all shade levels. This implies that the best overall preference for Arabica coffee was recorded by variety 744 under 50% shade level.

Results of the present study revealed that different Arabica coffee cultivars along with various shade levels affected coffee physical and cup qualities in different ways. Hence, appropriate shade level with a recognized variety can produce high quality coffee. To this end, although, it is difficult to give a conclusive recommendation by this single location and a year study, based on the result of the present study, the following points as priority research areas can be suggested for the future.

Coffee variety 744 under 70% shade level to improve the raw qualities and variety 744 under 50% to improve the cup qualities of Arabica coffee can be suggested for farmers of the study area.

Special attention should be given to coffee varieties under appropriate shade management along with provisions of extension and training services for quality improvement of Arabica coffee.

These approaches could be the best possible means to enhance awareness among coffee producers to keep typical coffee quality profile of their garden through shade tree management that finally adds value to their crop. It is therefore, advisable to apply these approaches at local level.

Further studies should continue giving more emphasis to multi-location evaluation of different shade levels against various Arabica coffee varieties to understand how these varieties react to diverse growing areas.

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7. APPENDICES

Appendix Table 1: Analysis of variance for bean size, hundred bean weight and preliminary quality analysis of Arabica coffee varieties subjected to various levels of shade at Jimma, 2014.

		Mean square values												
Source of variation	**DF**	**BS**	**Hbw**	**PD**	**SD**	**Od**	**TRQ**	**CC**	**Ac**	**B**	**Fl**	**TCQ**	**PT**
Block	**2**	*	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
Shade	**3**	**	***	**ns**	***	**ns**	***	**ns**	**ns**	**ns**	***	*	***
Error (shade)	**6**	**ns**	**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
Variety	**2**	*	**	*	***	**ns**	**ns**	**ns**	**ns**	**ns**	*	*	**
Shade * Variety	**6**	***	***	**ns**	***	**ns**	**	**ns**	**ns**	**ns**	***	*	**
Error	**16**												

Where: DF = Degrees of freedom; **BS**= Bean size; **Hbw** = Hundred beans weight; **PD**= Primary defect; **SD**= Secondary defect; **Od**= Odour; TRQ = Total raw quality; **CC** = Cup cleanness; **Ac** = Acidity; **B** = Body; **Fl** = Flavour; TCQ = Total cup quality; **PT**= Preliminary total. Level of significance ns, *, **, *** denoting ($P>0.05$ = ns), significant at ($P\leq0.05$), ($P\leq0.01$), and ($P\leq0.001$), respectively.

Appendix Table 2: Analysis of variance for speciality cup quality analysis of Arabica coffee varieties subjected to various levels of shade at Jimma, 2014.

		Mean square values							
Source of variation	**DF**	**Ac**	**B**	**Fl**	**Ar**	**Af**	**Ba**	**OP**	**TSCQ**
Block	**2**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
Shade	**3**	**ns**	**ns**	**	***	***	***	*	***
Error (shade)	**6**	**ns**	*	**ns**	**ns**	*	**ns**	**ns**	**ns**
Variety	**2**	**ns**	**ns**	*	**	*	**ns**	**ns**	**
Shade * Variety	**6**	**ns**	**ns**	**	***	**	**	*	***
Error	**16**								

Where: DF = Degrees of freedom; **Ac** = Acidity; **B** = Body; **Fl** = Flavour; **Ar** = Aroma; **Af** = Aftertaste; **Ba** = Balance; **OP** = Overall Preference; **TSCQ**= Total speciality cup quality. Level of significance ns, *, **, *** denoting ($P>0.05$ = ns), significant at ($P\leq0.05$), ($P\leq0.01$), and ($P\leq0.001$), respectively.

Appendix Table 3. List of coffee varieties, place of origin and characteristics

Variety	Origin	Suitable growing area	Commercial acceptance	Released year	Yield (quintal per ha)
744	Washi, Kaffa	Low-medium-high altitude	Acceptable	1979/80	16.6
7440	Washi, Kaffa	Low-medium-high altitude	Acceptable	1979/80	16.2
74110	Metu, Illubabor	Medium-high altitude	Acceptable	1978/79	19.1

Source: Beyetta *et al.*, 1998; Behailu *et al.*, 2008

Appendix Table 4. Preliminary cup quality analysis procedures

Preliminary cup for dry processed coffee		Total point and grade category	
Raw quality (40%)	Primary defect (15%)	Grade 1	91-100
	Secondary defects (15%)	Grade 2	81-90
	Odour (10%)	Grade 3	71-80
Cup quality (60%)	Cup cleanness (15%)	Grade 4	63-70
	Acidity (15%)	Grade 5	58-62
	Body (15%)	Grade 6	50-57
	Flavour (15%)	Grade 7	40-49
		Grade 8	31-39
		Grade 9	20-30
		Under grade	15-19
Total preliminary quality		Grade 1-3 qualifies for specialty coffee	

Appendix Table 5. Specialty cup quality analysis procedures

Specialty cup quality analysis		
Total specialty cup quality (100%)	Cup cleanness (10%)	**Specialty grade**
	Acidity (10%)	
	Body (10%)	Specialty 1 (Q1) :
	Flavour (10%)	≥ 85 points
	Aroma (10%)	
	After taste (10%)	Specialty 2 (Q2):
	Uniformity (10%)	≥80 points
	Sweetness (10%)	
	Balance (10%)	Commercial (Grade3):
	Overall cup preference (10%)	< 80 points

Grading

Green bean coffee samples evaluation and grading for both raw (40%) and liquor (60%) quality was carried out for 36 samples following the procedures of CLU (Coffee Liquoring Unit) (2007) as indicated in Table 1 and 2 below. The overall standard for raw and liquor quality grades range from 1 to 5, where, grade 1 = 81-100%, grade 2 = 61-80%, grade 3 = 41-60%, grade 4 = 21-40% or 1-2 defective cups, grade 5 = 20% or more than 2 defect. On the other hand, the overall standard for raw and liquor quality grades range from 1 to 5, where, grade 1 = 81-100%, grade 2 = 63-80%, grade 3 = 50-62%, grade 4 = 31-49% or 2 cups defect, grade 5 = 15-30% or more than 2 cups defect. Besides, a standard check with known quality attributes was also included in the evaluation for the purpose of comparison and judgment.

Appendix Table 6. Standard parameters and their respective values used for coffee liquor quality evaluation (CLU, 2007)

Liquor value (60%)					
Acidity	Points	Body	Points	Flavour	Points
Pointed	20	Full	20	Very good	20
Medium pointed	15	Medium Full	15	Good	15
Medium	10	Medium	10	Average	10
Light	5	Light	5	Fair	7
Lacking	2	Thin	2		

Grade Range: 1 = 81-100, 2 = 61-80, 3 = 41-60, 4 = 21-40 or 1-2 defective cups, 5 = 20 or more than 2 defective cups (defective cups: foul, earthy, and chemical).

Appendix Table 7. Standard parameters and their respective values used for specialty assessment on cup quality as per ECX (2010)

Cup	Quality Scale Points															
Quality	Good				Very Good				Excellent				Outstanding			
Fragrance	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Flavour	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
After taste	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Acidity	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Body	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Uniformity	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Balance	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Clean cup	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Sweetness	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75
Overall	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75