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EVALUATION OF COFFEE GROWTH, YIELD AND QUALITY UNDER COFFEE SHADE TREES AT MECHARA ON STATION, WEST HARARGHE ZONE, ETHIOPIA

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ABSTRACT

Coffee production with shade trees is important to improve growth and quality of coffee, sustain and restore agroecology and nature-based agroforestry practices. The trial was conducted at Mechara Agricultural Research Center (on station) in DaroLebu District of West Hararghe Zone, Oromia, Ethiopia. The study was intended to evaluate the influence of coffee shade trees on growth performance, yield and quality of coffee (Coffea arabica L.) under the canopy of Erytherina absinica, Cordia africana and Acacia sieberiana. The design was Randomized complete block design with three replications. The outcome had been observed a significant value at ($p<0.05$) probability level, non- significant value at ($p>0.05$) probability level and highly significance value at ($p<0.01$) probability level between treatments. Statistically significant and non- significant differences were observed between shaded and unshaded as well as within shaded effect based on the given parameters. Integration of shade in coffee farming system created creditable promising in producing organic coffee. Shade utility could be confirmed as to be ecologically sustainable, economically viable and socially acceptable practice. In so doing that, the effect of Erytherina absinica, Cordia africana shade trees illustrated the highest mean value in most parameters, while the least one is under the Acacia sieberiana shade tree. So the effect of Erytherina absinica mean observed with the highest value on total bearing plants 60%, thousand seed weight 59% and yield in Quintal per hectare 47.4% greater than the least treatments' mean value based on growth parameters. On the other hand, the effect of Erytherina absinica mean observed with the higher value on aromatic intensity 46.4%, aromatic quality 87.2%, acidity 92.4%, body 93.5%, flavors 88.6% and overall quality 88.6% than the least treatments' mean value, and also the effect of un-shade mean observed with the higher value on astringency 68.8% and bitterness 93.5% than the least treatments' mean value based on organoleptic parameters. The highest mean value of Erytherina absinica observed on total bearing plants 12.1, thousand seed weight 130 gram and yield in Quintal per hectare 5.7 based on growth parameters, while based on organoleptic parameters, the highest mean value observed under the effect

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of Erytherina absinica shade tree on aromatic intensity 4.5, aromatic quality 3.9, acidity 7.9, body 7.7, flavors 7.9 and overall quality 7.9. Therefore, based on the most treatments' parameters, to be the best shade tree was Erythrina abyssinica followed by cordia africana. Commonly, the dynamic indication of the treatment's means difference was indicated between shaded and unshaded rather than within shaded means variation at most treatments' parameters.

Keywords: Coffee-Based Agroforestry System, Coffee Shade Value, Coffee Growth, Coffee Quality Attributions

1. INTRODUCTION

Coffee is originated in the forest of East Africa that is in Ethiopia. It is adapted traditionally under the shade in order to pretend its natural habitat accounting for the fact that it has evolved to fit the normal physiological and structural characteristics. Coffee (Coffea arabica L.) is the most important agricultural shade lover goods and half of world's people take it in daily life process that more than 400 billion cups of coffee are consumed each year, which is exported from developing nations as to be the major source of foreign currency earnings (Illy E, 2002;) (Ferrell & Cockerill, 2012; Grades, 2007). The value of coffee for producers' country about $ 14 billion annual income generator and more than 18 countries, including Ethiopia, export coffee product to more than 165 countries providing a livelihood for an estimate of 100 million people around the world (ICO, 2001). Thus among 25 coffee producers, from African continent, Ethiopia is the first largest producer and the fifth of the world after Brazil, Vetinam, Indonesia and Colombia ((AfDB) (2010)).

Recently, coffee production with shade tree is the best example of agroforestry practice, which is to be improved environmental function and non-marketable ecosystem services such as recycling nutrients, providing habitat of biodiversity, maintaining natural resource as well as improving growth and quality of coffee, fodder for livestock production and increasing alternative income to the society from the sale of timber and non- timber forest products ((Michiel et al., 2004; Ríos & Ferguson, 2015).

Therefore coffee plant needs shade naturally on behalf of sustaining its production with reduces over-bearing, avoids branch die-back, disallows disease, and maintains growth parameter or physical yield and improves organoleptic quality. Coffee shade had an effect on physical yields of coffee plant such as number of branch, number of node per branch and number of fruit per node, and organoleptic qualities such as shape and make, color, bean size, aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor and overall quality (Diriba et al. (2017) Roba (2017) (Mark, 2005).

In the reverse, sun grown coffee increase the level of metabolism and improper morphological growth which are exposes for premature death of coffee plant, branch dieback, over bearing of fruits, fluctuation of fruit bearings, intensive use of chemical fertilizers, insecticides, herbicides, fungicides and need more management. These could be resulted for undermine of organic coffee yields and decreased the leading perineum price of coffee market (Mark, 2005).

However; coffee production in Ethiopia is high, the immense human pressure consumes forest coffee for different socio-economic utilities and mainly because of unsustainable resource use is one of the constraints for coffee production in the country. Hence farmers have cleared natural forest and around their farms for timber, firewood, construction, cultivation of other crops, settlement and establishment of plantations is also causing a reduction of the forest cover leading to destruction, fragmentation and degradation of the coffee habitats. On the other hand, only a few shade tree species are used in a limited area of coffee producers (Grades (2007)Gole and Senbeta (2008)).

Generally, in Ethiopia as population number has been increasing, while cultivable land shortage is creating then many coffee grower farmers abandoning their traditional system to intensive production through integrating of food crops with coffee production without shade trees. Especially this scenario has been appearing truly in west Hararghe zone of coffee producer districts. Thus, gradually the genetic resource of Coffea arabica which is shade lover has been disappearing at an alarming rate from the area, this rendering it for premature death of coffee plant, branch dieback, disease, over bearing of fruits, fluctuation of fruit bearings and undermines organic coffee quality (Diriba et al. (2017)) (Bote & Struik, 2011; Gole et al., 2002).

Therefore, to change these trends; evaluation of coffee shade tree species and its effect on coffee growth parameters, raw and cup coffee beans' quality had been evaluated in order to amend the value of coffee shade trees based on the following objectives.

1.1 OBJECTIVE

1. To select the suitable coffee shade tree species
2. To evaluate the effect of coffee shade trees on coffee growth, yield and Organoleptic coffee beans' quality

2. MATERIALS AND METHOD

2.1 DESCRIPTION OF THE STUDY AREA

The trial was conducted at Mechara Agricultural Research Center (on station). The center is located at 431 Km west of Addis Ababa. The altitude is 1780m a.s.l. Rainfall pattern in the area is bi-modal; kiremt rainy season (June, January, August and September) and belg rainy season (February, March, April and May). Average annual rainfall amount is 1145 mm.

High amount of rainfall is received in the April (l188 mm) and May (1395 mm) during the belg rainy season whereas high amount of rainfall is received in the month of July (1180 mm) and August (1462 mm) in the kiremt rainy season. Mean annual temperature is 21°C with mean annual minimum temperature of 13°C and maximum 27°C (Mechara agricultural research center, meteorological station 2009-2017 intervals) Figure 2 . Soil of study area is dominantly reddish brown Nitosols. They are generally clay dominated and are characterized by low available phosphorous with a pH ranging from 5.3 to 6 in surface soils. The vegetation cover of the area is woodland and open wooded grassland types.

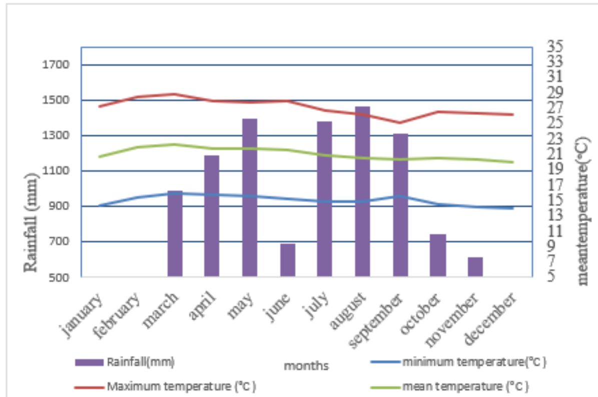

Figure 1 Rainfall and temperature of the study area from 2009-2017 years **Source:** (Mechara Agricultural Research Center, meteorological station data)

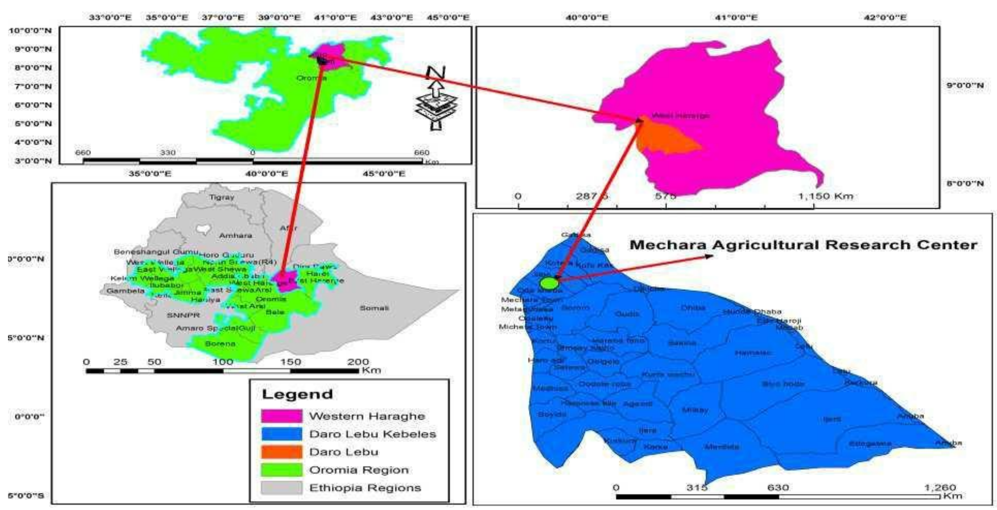

Figure 2 Map of the study area

2.2 TREATMENTS AND EXPERIMENTAL DESIGN

The selected coffee seed was (Mechara-1 Varity) that secured from Mechara Agricultural Research center. Coffee shade seeds were collected from surroundings Mother Trees. The collected seeds were sown directly on seed beds with polythentub plastic bags that were filled with 3 part local soil: 2 part sand: 2 part farmyard manure based on its time taken. The seedlings were raised at coffee nursery site of Mechara Agricultural office following the expected nursery recommendation practices. Seedlings of coffee shade trees (Erytherina absinica, Cordia africana and Acacia sieberiana) were planted in spacing of 4m distance from each other before one year of coffee seedlings plantation.

Then, the planting pits of coffee seedlings were prepared on experimental site with 2mx2m space gap between coffee plants and rows, and 4m gap between each plotsand between reps. The total number of plot was 12 in 3 replication with 3 shade tree species.

Finally, when the seedlings were reached for planting with the size of (25-35cm) and they were transplanted towards the experimental field in Randomize Completely Block Designed (RCBD) in three replications. One plot had 16 coffee plants and 4 shade tree plants; one shade tree to be shaded for 4 coffee plants. A plot was contain only the same shade tree species. As a control, three plots were planted with 48 coffee seedlings without coffee shade tree species.Whereas 144 coffee plants were planted under 36 shade trees (12 shade trees species in one rep from each species). The plantation area was 1672 m^2 that 38m *44m.

2.3 COFFEE SAMPLE PROCESS

The necessary data was collected starts the planting of coffee plants up to the coffee beard the beans. There was twelve representative coffee plants were demarked from each plot of shaded and unshaded part that purposively selected and assigned for sample collection.

Then, six coffee branches were selected and marked from the lower, middle and upper stick branch from west and east directions for each sample of coffee plants. The cherries were collected at the time of full ripping period, after planting of 5 years old. The coffee was too let to give a yield due to drought problem for three years of growing time, so the true yield was collected after six years ago. The sampled branches were counted and the number of fruits per node per branch was identified, which had been used to estimates yields of coffee per plant per hectare. The yield estimation was done based on sensibly with the logic of conversion factor that changing red cherries yield to clean coffee yield. Hence, the reasonable suggestion was taken based on the yield had been gained by correction factors (Hernández, 1995). 4kg of fully ripe coffee cherry beans were collected from each sampled plot and branch of coffee plants. Under both shaded and unshaded coffee trees, there were 36 samples of coffee bean were collected. The harvested coffee bean was dried until a constant moisture content of 12%. Then dry coffee beans were weighted using digital measuring balance on basis of 1000 seed weight of shaded and unshaded coffee plants from each coffee bean samples based on the procedures of (Siles et al., 2010;) (Bote & Struik, 2011).

2.3.1 COFFEE CHERRIES DRYING AND PACKING

The oldest and simplest method producing' natural' coffee is 'sun drying' that has been adopted throughout all coffee growing areas in Ethiopia, and this system was the only processing method. The cherries were spread out evenly on mesh wire to dry in the sun. Each sample cherries were dried until the recommended moisture content of 11-12% was attained.

Then after, the sample cherries were hulled with mortar as farmers have been practicing carefully and cleaned. Finally, the green coffee beans were labeled and packed in transparent polyethylene bags where berries stabilize their moisture content and quality attribute. The packed dry coffee bean was then transported to Jimma Agricultural Research Center for determination of the raw and cup coffee quality.The packed and collected samples were prepared using proper method of processing and arbitrary code (identity letter) was assigned to secure unbiased judgment. The packed dry coffee bean samples were transferred to coffee quality laboratory at Jimma Agriculture Research Center to evaluate the quality, based on the physical, raw, aroma and cup attributes.

2.3.2 SCREEN SIZE OF COFFEE BEANS

Bean sizes were determined by conventional screen analysis of perforated plate screen sizes of 14 with respective whole diameter of 5.55mm (Wintgens, 2004). 300g of each coffee samples were replicated three times and measured using digital beam balance.

The coffee beans were graded by 'size using standard screen' that have different screen size, with 'round holes' as defined by (ISO, 1991). The normal sizes of coffee beans were remained over the screen in order to determine their normality percentage while undervalued and broken beans were separated from each sample. Finally, the defect count percentage was recorded as per national fixed standard (JARC, 2008).

2.3.3 RAW COFFEE QUALITY GRADE EVALUATION

During physical quality analysis; 300g of green bean was used for each sample for their qualities attribute such as 'shape and make', color and odor. These quality attributes were measured according to the Ethiopian standard that based on raw quality parameters' grading was done in account of 40% as per ((ES, 2001; ECX, 2009).

2.3.4 AROMA AND CUP QUALITY GRADE EVALUATION

Three cups per treatment in three replications were prepared for each tasting session. The evaluation had been carried out by a panel of Jimma Agricultural Research Center panelist who formed a team of trained, experienced and certified quality

Graders and Cuppers in order to get aroma and cup quality values in account of 60%. In this case, three experienced tasters participated in a panel to evaluate coffee bean samples' aroma and taste characteristics of each treatment of coffee brew involving olfaction, gestation, and mouth feel sensation. For each sample using the round soup spoon raise six to eight cc of liquid to just in front of the mouth and forcefully slurp the liquid. Aroma was evaluated by sensation from brewed coffee that released gasses.

The released gasses were inhaled through the nose by sniffing and briskly/quickly aspiring, the coffee. In this way, spread evenly over the entire surface of the tongue. Sensory evaluation was done using the following quality criteria in scale range of (AI, AQ, AC, AS, BI, BD, FL and OAQ) value. Based on these measures, the scale comprised the point ranged from 1-15 was used. The sensation was obtained from the gases released from roasted and ground coffee beans as aromatic compounds. In order to evaluate sample of ground coffee quality, the gasses were inhaled through the nose with sniffing/smelling aroma and the inhaling process revealed the nature of coffee bean taste /typicity such as floral, moca, spicy, etc.

2.4 DATA COLLECTION

Table 1 Data of coffee shade trees, growth and yield of coffee, and quality of raw and cup coffee beans

Growth and yield parameter of coffee plants	**Aroma and cup coffee beans' quality parameters**
• Number of branch	• Aromatic quality
• Number of node per branch	• Aromatic intensity
• Number of branch dieback,	• Acidity
• Number of fruit per node, • Number of bearing coffee plants	• Astringency • Body and Bitterness
• 1000 seeds weight in gram,	• Flavor
• clean yield in quintal per hectare	• Overall quality
The growth parameter of shade trees	**Raw coffee beans' quality parameters**
• Canopy coverage	• Screen size of coffee beans
• Diameter(DBH)	• Shape and make
• Height	• Color and odor

2.5 DATA ANALYSIS

The collected data was analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using SAS statistical software of 9.1.3 versions. The important variation, mean separation using LSD was conducted at 5 % point of significance level.

3. RESULT AND DISCUSSIONS

3.1 CANOPY COVERAGE, HEIGHT AND DIAMETER AT BREAST HEIGHT OF COFFEE SHADE

Table 2 The mean value of Coffee shade tree growth parameters

Coffee shade	Ccrg (m)	PH(m)	DBH(cm)
Acacia sieberiana	6.8a	4.4a	13.9a
Cordia africana	5.1b	3.9a	8.4b
Erythrina abyssinica	2.6c	2.7a	7.1b
LSD (5%)	1.5	2.3	5
CV (%)	13.5	27.9	22.6

Ccrg= Canopy coverage, PH= plant height in meter, DBH= Diameter at breast height=meter; cm=centimeter

The highest mean of Acacia sieberiana greater than the lowest mean of Erythrina abyssinica (61.8%) based on the Canopy coverage parameter (Table 2). Under the plant height, the height value greater than the lowest mean with (38.6%) on treatment of Cordia africana and Erythrina abyssinica respectively (Table 2). The highest and lowest means difference is (48.9%) that recorded under Acacia sieberiana and Erythrina abyssinica based on Diameter at breast height respectively (Table 2).

Generally, the higher yield could be found under the lowest canopy coverage that is Erythrina abyssinica shade tree, inversely the lowest yield also found under higher canopy coverage of Acacia sieberiana shade tree (Table 2). Similarly, canopy of shade has a positive effect on yield of per coffee plant, if the canopy coverage is between 15% and 54, otherwise less than or greater than these range, it has a negative effect on yield of per coffee plant (Gao, Yixuan, 2018).

3.2 EFFECT OF COFFEE SHADE TREES ON GROWTH AND YIELD OF COFFEE PLANT

3.2.1 NUMBER OF BRANCH PER COFFEE PLANTS

The highest mean value of branch per coffee plant was observed at unshaded coffee plants, while the least mean value of a given treatment showed under Acacia sieberiana shade tree (Table 3). The mean value of number of branch per coffee plants showed statistically non-significant difference; but there is a variation between mean values numerically. So, the highest mean of unshaded coffee greater than the lowest mean of Acacia sieberiana is 31% based on the given parameter (Table 3). However; higher number of branches and number of node per coffee plant were recorded under unshaded coffee plants, the coffee plants physiologically stunted and deformed which were affected with branch dieback at the tip. Unlikely to other coffee shrubs which are found under shade trees effect.

Table 3 The mean value of coffee growth and yield under the effect of shade trees

Trt	Parameters						
	nbrch	**nndprbch**	**brcdbk**	**frtprnd**	**ttbplt**	**Sswt(gm)**	**yldQtl/ha**
E.abyssinica	26.7ab	10ab	2b	6.7a	12.1a	130a	5.7a
C.africana	24.3ab	10ab	2.7b	6.7a	7.7a	119.3ab	5.3a
A.seiberina	20b	8.7b	3.7b	4.3a	7.3a	76.7b	2.7a
Un shaded	29a	11.3a	7a	7.3a	8a	106.7ab	3.8a
LSD (5%)	8.7	2.6	5.2	3.3	5.2	55.2	3.1
CV (%)	17	12.8	28.5	31	33.7	23	36

Nbrch=number of branch; nndprbch=number of node per branch; brcdbk=branch dieback; frtprnd=fruit per node; ttbplt=total bearing plants; Sswt(gm)=1000 seed weight; yldQtl/ha=yield in quintal per hectare

In the contrary; the highest mean value of branch per coffee plant was observed under shaded coffee plant that due to a higher content of organic matter under the tree canopies than in the open area as higher addition of the litter falls, dead roots from the shade trees accumulated under the canopies then altered soil properties (Roba (2017)).

In general, this finding might be due to the effect of vary with age of shade, climatic variation, density, site conditions, management and particularly with soil fertility to modify light availability for specific requirements of both plants.

3.2.2 NUMBER OF BRANCH DIEBACK PER COFFEE PLANTS

The highest mean value of branch die back observed at unshaded coffee plants, while the least mean value of a given treatment showed under Erythrina abyssinica shade tree (Table 2). The mean value of number of branch dieback per coffee plant showed highly significant difference at ($p<0.01$) probability level based on the given parameters; therefore there is a variation between mean values statistically. So, the highest mean is greater than the lowest mean with 69% between treatment of unshaded coffee and Acacia sieberiana coffee plants (Table 3).

Similarly, unshaded coffee stands exposed to excessive evapotranspiration and sever water stress, death of actively growing branch, seasonal crinkling of leaves and subsequent yield reduction due to frost damages “hot and cold as well as bio-physiochemical disorder of coffee plants” (Taye et al., 2007).

Generally, the number of branch dieback of per coffee plant was higher under unshaded coffee plants, while the least number of branch dieback was recorded under Erythrina abyssinica shade tree. This effect indicated that the shade tree might be increased the number of microorganism to decompose litter fall inputs in addition to other factors, which are to be a better attributers of positive effect for normal physiology of coffee plants.

3.2.3 NUMBER OF NODE PER BRANCHTable 3

The highest mean value of number of node per branch observed under unshaded coffee plants, while the least one showed under Acacia sieberiana shaded coffee plants (Table 3). The mean value of number of node per branch showed statistically non-significant difference between treatments based on the given parameters; but there is a variation between mean values mathematically. So, highest and lowest means difference is (24%) and that recorded the difference between under unshaded coffee plants and Acacia sieberiana shaded coffee plants based on number of node per branch (Table 3).

3.2.4 NUMBER OF FRUIT PER NODE

The available mean value of number of coffee fruit per node showed statistically non-significant difference between a given treatments. But based on the mean difference, there is a variation between treatments that is 69% difference between the highest and the lowest value of number of fruit per node due to shade effect (Table 3). The shade has a positive effect on the yield of per coffee plant, if the canopy of shade tree is between 15% and 54% coverage unless it has negative effect on coffee yield (Gao (2018)).

Similarly the study of (Soto-Pinto et al. (2000)) approved that, when the canopy coverage exceeds the threshold ranges, it may decrease on the number of fruit per node or per coffee yield. Therefore; the lowest value of a given treatment is recorded from Acacia sieberiana which has dense canopy coverage over the coffee shrubs (Table 3).

In general, canopy of coffee shade tree might be beneficial to coffee yield components within a certain range, likely due to the competition between shade trees and coffee shrubs for soil water retention, soil fertility and ecosystem services specially provided by the shade trees.

3.2.5 TOTAL NUMBER OF BEARING COFFEE SHRUBS

In this study, the mean value of total number of bearing coffee shrubs revealed statistically non- significance differences between a given treatments. But there is a difference between mean values. Therefore, the highest and lowest means difference is (39.7%) recorded between Erythrina abyssinica and Acacia sieberiana shaded coffee plants based on the number of bearing coffee shrubs (Table 3).

Various researches conducted previously at different places came up with results that are somewhat related ideas to the present study. These related ideas narrate to this thought that higher shade density had a negative effect on coffee bearing trees. However; some studies showed higher yields of coffee can be obtained from intensively managed of unshaded coffee plants, probably because of widely varying site conditions, management and other factors. When comparing shaded versus unshaded coffee or comparing different shade species, a group of factors vary rather than just the factor 'shade tree species (Somarriba et al., 1996).

In this study, the variation in "number of bearing coffee shrubs" between shaded and unshaded effect was quite logical as a result of the above reasons. Generally shade makes a coffee plant to persist fruit bearing condition with sustainable manner without any physiological and morphological problems.

3.2.6 THOUSAND COFFEE FRUITS' WEIGHT

The study revealed that available mean value of '1000 seed weight in gm' showed statistically non-significance difference between a given treatments. But there is a variation between means. The highest mean value of 1000 seed weight in gram was observed under Erythrina abyssinica shaded coffee, while the least mean value was under Acacia sieberiana shaded coffee plants that with 40% mean difference (Table 3).

The highest weight of coffee fruits observed under medium shaded coffee plants that might be due to shade tree species effect which is donated the highest amount of nutrient availability from the litter fall for improved nitrogen mineralization rates with the exception of other factors.

Similarly, Ebisa (2014) report, there was an observed relatively higher coffee weight of 1000 beans in gram under shaded zone than under unshaded zone of coffee plants even if the difference was not statistically significant. Similarly, the finding of Geromel et al. (2008) indicated that coffee weight was significantly higher in shade zone.

Therefore, 1000 seed weight of highest coffee fruit yielder showed under Erythrina abyssinica shaded coffees which can be taken as to be the superlative coffee shade tree based on its effect (Table 3).

3.2.7 CLEAN YIELD OF COFFEE IN QUINTAL PER HECTARE

The mean value of clean coffee yield observed non-significant difference between a given treatments. But there is a difference between the observed means, that the highest mean value of a given treatments observed under Erythrina abyssinica shaded coffee, while the least mean value is under Acacia sieberiana shaded coffee (Table 3). Therefore, between the highest and lowest mean difference of a given treatment is 87.7% vary.

Similarly, coffee productivity under the shade of Erythrina abyssinica had a much higher productivity than other shades (Hergoual'ch et al., 2007). According to Hernández (1995) report specified that yield of green coffee beans was 0.6% higher under shaded than open one, which translated in to an additional of 44 kg ha-^{1} green coffee beans. Earlier study of Muleta et al. (2011) from south west Ethiopia was also confirmed higher coffee yield from shade grown coffee. In the contrary, coffee beans yield was reported to be relatively higher in unshaded coffee zone (Bote & Struik, 2011).

Generally, in this result, truly imitated other's idea that canopy of coffee shade has a positive effect on the coffee yield of per coffee plant, if the canopy range is between 15% and 54% coverage unless it has negative effect on the yield of per coffee plant (Gao (2018)). This might be the result of improved nitrogen mineralization rate under the optimum shade effect of Erythrina abyssinica tree, related to the higher level of biomass recycling and nitrogen fixation with the exception of other factors.

3.3 EFFECT OF SHADE TREES IN ORGANOLEPTIC COFFEE BEANS' QUALITY

Table 4 The mean value of raw coffee beans under the effect of shade trees

Treatments	Shape and make	Color	odor
	15%	**15%**	**10%**
Erythrina abyssinica	13a	13.1a	10
Cordia africana	12.7a	13.2a	10
Acacia sieberiana	11.1b	11.2b	10
Un shaded	11b	11.1b	10
LSD (5%)	1.7	2.2	0
CV (%)	2.5	4.5	0

3.3.1 EFFECT OF SHADE TREES ON RAW COFFEE BEANS IN SHAPE AND MAKE QUALITY

In this study, the mean value of parameter observed to have significant difference ($P<0.05$) between a given treatments effect in the availability of shape and make of raw coffee quality test. The highest mean value of the given treatments' parameter was observed under Erythrina abyssinica shade tree influence but under unshaded effect.

According to Bote and Struik (2011), research report, shaded coffee resulted in heavier and larger coffee beans and a good "shape and make" than unshaded coffee fruits. This research report, confirmed with the present study. This might be mainly due to its effect on temperature and the duration of the ripening period.

3.3.2 EFFECT OF SHADE TREES ON RAW COFFEE BEANS IN COLOR QUALITY

The mean value of treatments indicated significant difference ($P<0.05$) between shade tree species as well as open areas' effect on the availability of color at raw coffee quality test. The highest mean value on the treatments' parameter was Erythrina abyssinica shade trees, while the lowest mean value of the given treatments' parameters was observed in unshaded coffee plants. Color is the visual appearance of the brewed cup of coffee. Ones' aspect of visual appearance indicates color and the direct effect of caramelization power of the sugar beans based on roasting degree. The roasting degree also depends on the size and 'shape and make' of green coffee beans. So the shade may have an influence on color availability indirectly hence and Categories of the rate of results were found under the rooted in its referred scales similarly in (Table 4).

3.3.3 EFFECT OF SHADE TREES ON CUP QUALITY OF COFFEE BEANS IN AROMATIC INTENSITY

Table 5 The mean value of aroma and cup coffee beans under the effect of shade trees

Treatments	AI	AQ	AC	AS	BI	BO	FL	OAQ
	5%	**5%**	**10%**	**5%**	**5%**	**10%**	**10%**	**10%**
Erythrina abyssinica	4.5a	3.9a	**7.9a**	4.4a	4.4a	**7.7a**	**7.9a**	**7.9a**
Cordia africana	4.1a	3.8a	7.3a	3.4b	4.3a	7.4a	7.3b	7.3ab
Acacia sieberiana	2.9b	3.6a	**7.5a**	3.1b	4.5a	7.3a	7a	7.1a
Un shaded	3.5b	3.4a	8.2a	**4.5a**	**4.6a**	7.2a	6.9ab	7b
LSD (5%)	1.2	1.7	1	1.2	0.3	0.7	1.8	1.8
CV (%)	13	20	5	4.8	9.2	4.6	4.8	5

Note-AI=Aromatic intensity; AQ=Aromatic quality; AC=acidity; AS=astringency; BI=bitterness; BD=body; Ttlgrad=total gradeFL=flavors; OAQ= overall quality

The mean value of treatments showed significant difference (P<0.05) between shade tree species and unshaded areas' effect in the availability of aromatic intensity at cup coffee quality (Table 5).

The highest mean value of aromatic intensity was observed under Erythrina abyssinica shade tree effect, while the lowest mean value of the given parameters was also displayed at unshaded coffee plants (Table 5).

Aromatic intensity, the gaseous natural chemical components of roasted and brewed coffee is given off when coffee is roasted and brewed. Aroma is a responsible for all coffee flavor attributes. The shade may have indirect effect on availability of aromatic intensity.

According to results' discussion was stated at different tables in this study, the shade trees might be have a direct and indirect effect on coffee production through the process with buffering the physiological part of coffee plants, from natural phenomenon. Thereby the coffee beans made uniform bean size due to indirect effect of shade trees and the rate of parameter was based on its description of the scale in (Table 5).

3.3.4 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN AROMATIC QUALITY

The mean value of treatment observed non-significant difference at (P>0.05) probability level between a given treatments based on the parameter that on aromatic intensity (Table 5).

However, statistically it showed non-significant difference at (P>0.05) probability level; there is aviation between the means. So the highest mean value of treatment was recorded under Erythrina abyssinica shade tree, while the lowest mean value of the given treatments' parameter was recorded under unshaded coffee (Table 5).

Similar outcome was reported by (Diriba et al. (2017)). Aromatic quality indicates smell of the liquor sensed either by direct inhaling of the vapors arising from the cup or by nasal perception of volatile substance evolving in the mouth found as multiple aromatic compounds' quality. So the shade tree'sresult designated to have typicity values of the given parameter to be 'slightly moca and spice' perfume by professional cup liquor panelist of (JARC, 2008) group and the rate of parameter was based on its description of scale in (Table 5).

3.3.5 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN AROMATIC

The mean value of treatment effect observed statistically non-significant difference (P<0.05) between the given treatments based on this parameter, in the availability of acidity at cup coffee quality test but there is aviation between their mean differences (Table 5).

The highest mean value of acidity was recorded under Erythrina abyssinica shade tree, while the lowest mean value of the given parameter observed from unshaded coffee plants (Table 5). The literatures reflected that high acidity of cup coffee quality had reported defiantly from shaded areas of the coffee farm than open areas (Siles et al., 2010;) (de Souza et al., 2012). According to Agawanda (1999), acidity of coffee cup tests are reliable and suitable quality attributes that can be used as selection criteria for the genetic improvement of the overall liquor quality had got from shaded coffee beans than unshaded beans.

The higher value of acidity percentage in cup quality test was found under shaded coffee beans, while the least mean value under open coffee beans. This might be, due to high pH value under the shade, which influences acidity of coffee bean cup quality test under the canopies (Roba (2017)). Acidity indicates the bitter or acidic balance that a sweet car melic after taste which could be affected by roast degree and phonology of coffee fruit that means shade may have indirect effect on coffee cup quality test.

3.3.6 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN ASTRINGENCY QUALITY

The mean value of treatment observed a significant difference (P<0.05) between a given treatments in the availability of astringency at coffee cup quality test (Table 5).

Many researchers reported that the higher content of astringency of the coffee beverage may be due to higher content of sucrose and chromogenic acid in green coffee beans based on its size and ripping paired. This chromogenic acid is reduced to organoleptic quality especially under unshaded beans than shaded ones (Morais et al., 2006). Shade tree play a great role in producing heavier and larger coffee beans size which is depends on temperature effect and the duration of ripening period to have quality physiological fitness of coffee beans (Siebert, 2002). So in this study the higher value of astringency was observed under unshaded part of coffee plants (Table 5) and the rate of parameters ware based on scale description in (Table 5).

3.3.7 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANSIN ACIDIC QUALITY

The mean value of treatments effect did not show significant difference (P>0.05) in the availability of bitterness at the given treatments' parameter between the given treatments (Table 5).

But the highest mean value of the given treatment was observed unshaded coffee beans, while the least mean value was observed under shade tree effects (Table 5).

The higher content of bitterness of the coffee beverage may be due to higher content of sucrose and chromogenic acid in green coffee beans based on its size and ripping paired. This chromogenic acid optimally influences organoleptic quality especially under unshaded than shaded ones (Morais et al., 2006). So in this study, the highest mean value of bitterness was observed under unshaded coffee beans, than that of shaded coffee beans' quality. This may be due to its size and ripping paired beside other factors that due the direct sun light could be predisposed the chromogenic acid which is optimally influences organoleptic quality especially under unshaded coffee beans and the rate of parameters was based on description in (Table 5) scale rages.

3.3.8 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN BODY QUALITY

The mean value of treatment effect had non- significant difference (P>0.05) in the availability of body at cup coffee quality test between but there is a difference between there means. The highest mean value of treatments' parameter was observed under Erythrina abyssinica shade trees, while the lowest mean value observed at open coffee beans (Table 5). Available of body in a cup of coffee quality test indicates viscosity or thickness of coffee brewed. It is the physical property of beverage that the result in tactile sensations perceived on the skin in the mouth during that after ingestion based on beans quality (JARC, 2008).

According to Agawanda (1999), body of coffee cup tests are reliable and suitable quality attributes that can be used as selection criteria for the genetic improvement of the overall liquor quality had got from shaded coffee beans than unshaded beans. Shade alter directly and indirectly organoleptic result in coffee quality aspect beside to other factors that dark roast enhance the body while light roast emphasize acidity (; ITC, 2002) (Muschler, 2001). The study was also confirmed the above ideas that the higher mean value of the given treatments' parameter was observed under the shaded coffee plants' beans (Table 5) and the rate of parameter s ware submitted by description of (Table 5) scale rages.

3.3.9 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN FLAVOUR QUALITY

The mean value of treatments indicated statistically non-significant difference ($P<0.05$) in the availability of flavor at cup of coffee test between a given treatments. The mean value of flavor at cup quality test that influenced by shade tree canopy was higher than that of open area under Erythrina abyssinica shade tree effect (Table 5).

Flavor is the simultaneous sensation in the test of aroma and taste. Coffee aroma is composed of the gaseous natural chemical components of roasted and brewed coffee beans, which escape as vapors after the coffee grounds are brewed. The perfume of the ground roasted coffee before water is added, it gives fragrance/aroma and one can smell the aroma, evaluate the body then perceive the taste and flavors (Muschler, 2001). The higher mean value of treatments' parameter was observed under the shade, while the lowest mean value was observed under unshaded coffee plants. This may be due to indirect effect of shade trees and the rate of parameters ware submitted by description of (Table 5) scale rages.

3.3.10 EFFECT OF SHADE TREES ON CUP OF COFFEE BEANS IN OVERALL COFFEE QUALITY

The mean value of treatments observed statistically non- significant difference ($P<0.01$) between the given treatments. But there is varies between mean value on availability of the given treatments' parameter (Table 5). The highest mean value of the given treatments was observed under shaded coffee beans, while the least mean value observed from unshaded coffee beans (Table 5).

The total quality of coffee, based on overall quality attributes was used to determine quality potential (Muschler, 2001). The higher value of the given treatments' parameter was observed under the shade trees effect.

3.4 COFFEE GRADING BASED ON RAW AND CUP COFFEE BEANS' QUALITY EVALUATION

The raw coffee quality evaluation based on their "shape and make", color and odor were computed along with the set of (ES, 2001; ECX, 2009). The highest mean value of raw quality analysis was found from the Erythrina abyssinica shade tree's effect

Table 6 Grading value of raw, aroma and cup coffee beans quality

Table 5: Standard and respective mean values used for unwashed raw coffee beans, and cup and aroma coffee beans value

Trt	Sp & mk	Colo	odo	TRQ %	AI	AQ	AC	AS	BI	BO	FL	OAQ	TCPQ %	Ttl-grd%
	15%	15%	10%	40	5%	5%	10%	5%	5%	10%	10%	10%	60	100
Erythrina abyssinica	13	13.1	10	36.11	4.5	3.94	7.89	4.44	4.44	7.72	7.94	7.89	48.78	85
Cordia africana	12.67	13.1	10	35.83	4.17	3.83	7.33	4.33	4.33	7.17	7.33	7.33	45.83	82
Acacia sieberi-ana	11.1	11.2	10	32.3	2.9	3.6	7.5	3.1	4.5	7.3	7	7.1	43	75.3
Un shaded	11.67	11.0	10	32.75	3.58	3.42	8.17	4.5	4.67	7.33	6.92	7	45.58	78

Note; Scale of Sp&mk=shape and make:- v. good=15; Good =12; Fair good=10; Average=8; Mixed =6; Small =4" Scale of Color:-Bluish =15; Grayish =12; Greenish =10; Coated =8; Faded=6; White =4" " TCPQ=Total cup quality; AI=Aromatic intensity; AQ=Aromatic quality; AC=acidity; AS=astringency; BI=bitterness; BD=body; Ttlgrad=total grade; FL=flavors; OAQ= overall quality; TCPQ=total cup quality * "The first grade coffee sample was determined as slightly moca and slightly spicy flavors as per (JARC, 2008)"; "After the raw and cup quality values summed the: 1^{rst}grade =81-100%, 2^{nd} grade =63-80%, 3^{rd} grade =50-62%, 4th grade =31- 49%"

followed by Cordia africana based on the given parameters, relatively. The summations of parameters were given its grading value as per (JARC, 2008) standard with 40% accounting shown as (Table 6).

The highest mean value of aroma and cup quality analysis of a given parameters was found from Erythrina abyssinica shade tree's effect followed by Cordia africana in the given parameters, relatively. Each quality attribute, after laboratory processing was subjected to statistical descriptive analysis, which was based on treatment effect. The total of raw quality (40%), and aroma and cup quality (60%) summation values ware used for final quality grading judgment in accounting of (100%) based on (ES, 2001; ECX, 2009) procedure as per (JARC, 2008) standard.

The highest quality grade range and typicity sense of 'moca' and 'spice of a given quality attributer were observed under shade tree effect in the given parameters (Table 6).

4. CONCLUSIONS AND RECOMMENDATIONS

In Ethiopian coffee production become deteriorates from time to time because of daily and annual climatic variation due to deforestation of natural forest and integration of food crops with coffee production without shade trees. Coffee growers encountered up normal growth of coffee plants which have negative impact on coffee yields due to sun grown coffee. Moreover, un shaded coffee plants have wilted and stunted coffee growth, branches, and needs more management and input is required for coffee plants.

The pressure from rapidly growing human population has been directly and indirectly shrinking welfare natural resources by means of deforestation. So production of coffee with shade tree is an agroforestry practice to improve production quality and sustain environmental biodiversity. This practice should have to be promoted and demonstrated in most districts of Hararghe zone for the place where coffee farmlands nearly wiped out and have been replacing with Khat and food crops.

Therefore, Erythrina abyssinica can be taken as the best shade tree for coffee production at the ideal level of canopy coverage in the aspect of optimizes the competition between shade trees and coffee shrubs in resource utilization. Successively, in almost all parameters, the best results were found under Erythrina abyssinica shade tree's effect followed by Cordia africana. So Erythrina abyssinica shade tree's outcome has to be designated to have better effect than other shade trees' effect. So, based on the investigated effect of treatments, it can be recommended that the remarkable coffee shade tree.

In general, the present study indicates that a substantial contribution of coffee shade trees for coffee production improvement, this could not be an end itself. Much more research work needs to be done in the following hesitation area of research potential:

The further schoolwork should be conducted towards scientific research study of shade trees' spaces for coffee plantation. Additionally, should be investigated associations of Erythrina abyssinica and Cordia africana shade trees with micro floral population of Rhyzobia and mycorrhizal fungal species are a principal importance, if being correlated with them which is may be good for production quality.

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