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Evaluation of Coffee (Coffea arabica L.) Physical Yield Aspect under the Canopy of Cordia Africana and Erythrina abyssinica Shade Trees Effect in Arsi Golelcha District, Ethiopia

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Abstract
Coffee plantation with shade trees is important to increase coffee production, sustain and restore agroecology and nature based agroforestry practices. The study was conducted on farmers' fields in Golelcha District of East Arsi Zone, Ethiopia. The study was intended to evaluate the influence of coffee shade (under the canopy of Erythrina abyssinica and Cordia africana trees) on growth performance and yield of coffee (Coffea arabica L.) and to get best coffee shade trees and appropriate distance of coffee seedling plantation area in which away from shade tree trunks. Randomized complete block design on three farmers' fields as a replication in each PAs were used for data collection. A total of 48 circular samples were taken for treatments' parameters, under both coffee shade tree species at the distance of 1m, 3m, 6 m and 25m away from shade tree trunk including unshaded zone. The two widely grown indigenous coffee shade tree species in the area were Cordia africana and Erythrina abyssinica. Even though farmers' preference focused on Cordia africana tree based on its utility, the best results were recorded under Erythrina abyssinica tree. The outcome had a significant value at ($p<0.05$) and highly significance value at ($p<0.01$) between and within the treatments. Statistically significant comparison differences were observed between shaded and unshaded as well as within shaded effect based on the parameters across PAs. Integration of shade in coffee farming system created creditable promising in producing organic coffee. Shade utility was also adopted as ecologically sustainable, economically viable and socially acceptable practice. The second distance layer (3m) away from shade tree trunks illustrated the highest mean value across PAs in most parameters. Almost all the given coffee parameters' value increased significantly under the tree canopy than in the open area in both PAs showing decreasing trend with increasing distance from the tree trunk. Average result of both PAs' coffee; the greater value of branch/coffee plant; 13%, and 19%, all fruits/ coffee plant; 5,060 and 9,740, thousand seed weight; 23% and 41% and clean coffee yield/ ha in qtl; 3.25% and 6.1%, than open areas were detected under the canopies of Cordia africana and Erythrina abyssinica shade trees, respectively. The best shade tree was Erythrina abyssinica and the recommended distance of coffee seedling plantation area away from shade tree trunk was 3m. Generally, the vital signal of the treatment's means difference were indicated between shaded and unshaded rather than within shaded means variation at most treatments' parameters.
Keywords: Coffee-based agroforestry system, physical Coffee yield and coffee shade value

1. INTRODUCTION

1.1. Background and Justification

In many parts of the world, small scale coffee growers use multi-purpose trees as a shade, shelterbelt and windbreaks to prevent coffee plants from excessive sun and high temperatures (journal of Travis and Idol, 2010). 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 (Illy E, 2002). 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, 2002).

In African continent; among 25 coffee producers country, Ethiopia is the first largest producer and the fifth of the world after Brazil, Vetinam, Indonesia and Colombia based on agroforestry system (AfDB, 2010). In addition, more than 50 developing countries are earning 25 % of their foreign exchange from coffee (CTA, 1999; ITC, 2002). In Ethiopia, about 25 % of the total populations of the country are dependent on production, processing, distribution and export of coffee. It accounts for more than 25 % of the GNP, 40% of the total export earnings, 25 % of the employment opportunity for both rural and urban dwellers, and 10 % of the total government revenue GDP (CTA, 1999; MoARD, 2008). Coffee grows at various altitudes, ranging from 550 to 2750 meter above sea level (m a.s.l). However, Arabica is best thrives and produced between altitudes of 1300 and 1800 meter above sea level (m a.s.l) with annual rainfall amount ranging from 550 to 2500 mm with an ideal minimum and maximum air temperatures of 15 and 25 0c (CTA, 1999; Bayetta, 2001).

Coffee production with shade is one of the best instances of agroforestry practices of organic farming system in Ethiopia. It is a worldwide issue given attention to sustain and restore nature. Organic agriculture promotes acceptability of production and sustainability of natural resource utilization so that ecological and economical contribution of shade tree in coffee production based on agroforestry practice to be taken as the best example of organic coffee (Mark, 2005). This organic agriculture could be gained by application of nature with nature for nature and it has been reflecting carbon sequestration which can be'sold'to developed nations to pay compensation for developing countries as a shade advantage (Mejia, 2007).

The Shade tree improve genetic resource of Coffea arabica, biodiversity and ecological management strategy. Additionally, diversify income opportunity and sustain ecosystem service (Gole et al., 2002). Arabica Coffea is self-pollinator and a heavy flower initiator plant species. So as to develop such heavy flower to fruit rapidly, it needs high carbohydrate, shelter and other essential soil nutrients unless and other-wise roots damage leaves abscise and branch dies back to the petiole. These are directly coincide with shade advantage on coffee value for price determine based on physical beans quality (Yunianto, 1986).

Internal pressure of coffee shade utility value for coffee producer countries to stabilize environmental impact and diversify the system from insecure mono-cropping to secure poly-cropping economy, and change the high input for 'green revolution' in national production system (Promecafe, 1995). Shade trees enable coffee plants to develop periscarp and perisperm tissue, vital syntheses of sucrose and phosphate enzymes in which higher peak of action in developing endosperm bandannas are detected for normal and acceptable coffee beans size maturity (Steiman,2003; Geromele et al., 2008).

Accordingly, shade tree reduced the vapor pressure between the interior of the leaf and the atmosphere to minimize high leaf temperature (Chege, 2011). Since coffee had been found in the forest, it naturally needs shade for sustained production of coffee yield and for its overall health (Ferrell and Cockerill, 2012). Shade tree improves coffee production moderately for a long period of time and it reduces evapotranspiration that favor condition of microorganism activation to endure drought without adverse effects of micro climate adoption to the nearby crops (Kim *et al.,* 2004) as compared to fully sun grown coffee plants.

However, population number is increasing; it is creating cultivable land shortage. As many coffee grower farmers, by abandoning their traditional coffee growing system, have begun integrating food crops with coffee plants without shade trees. This lately adapted system made farmers expose their coffee plants to intensive use of chemical fertilizers, insecticides, herbicides and fungicides which resulted in coffee plants; over bearing problem and branch dieback (Oman, 2001). This condition caused by farmers' is in East Ethiopia, especially on coffee farm in Hararghe zones' (McARC, 2005).

The district was selected for this study based on the fact that, it is one of the major organic coffee producer based on the shade trees effect. Therefore; the study was carried out in order to evaluate the effect of shade tree on coffee (*Coffea arabica L.*) physical yield aspect. In doing so, importance of the study was indicated the following points: (a) to fill the gap of local practice with scientific implication and encourage indigenous knowledge concerning to coffee shade tree utilization and species selection (b) to magnify understanding of government and other stockholders towards shade trees utility and (c) to be a base-line study for further scientific research extension to promote the recommended technologies for other coffee growers area, specially Western and Eastern Hararghe Districts which are coffee producers without shade trees.

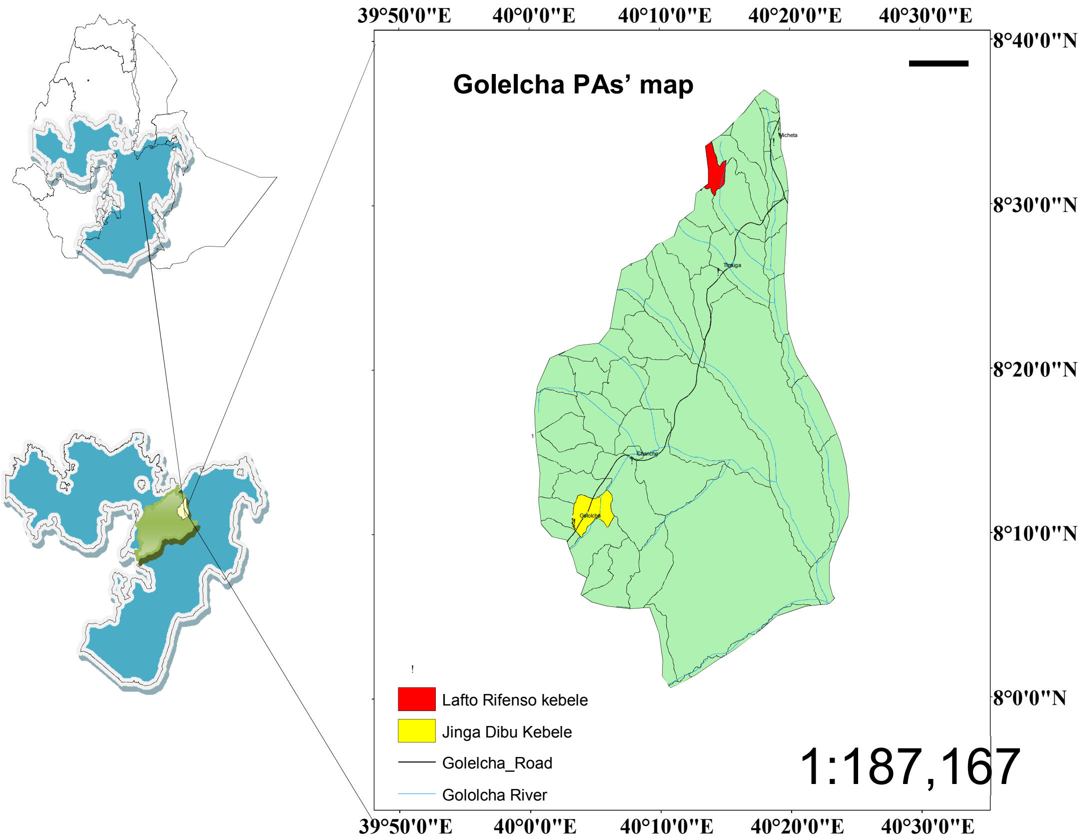
2. MATERIALS AND METHODS

2.1. Description of the Study Are

2.1.1. Location

According to Oromia livelihood profile (2006), Golelcha (figure 1) is one of the Districts found in Arsi Zone, Oromia Regional state of Ethiopia. It is located 307 km south east of Addis Ababa Ethiopia's capital city. The geographical coordinate of the area is between 08°00'0" and 08°37'00" N and 40°00'00" and 40°29'00" E.

Figure 1 Study area map of Arsi Golelcha district (Source: Ethio-GIS lab in Haramaya University)



2.1.2. Climate and Rain fall

The study district experiences mean annual and monthly minimum and maximum temperature of 15 and 27°C, respectively and receives mean annual and monthly rainfall (figure 2) is 550 mm in the year of 2015 crop season. The seven years data of mean annual and monthly rainfall (figure 3) in the district are 703 mm minimum in the year of 2012 and 1486 mm maximum in the year of 2013 respectively which characterize the area having a bimodal rainfall type.

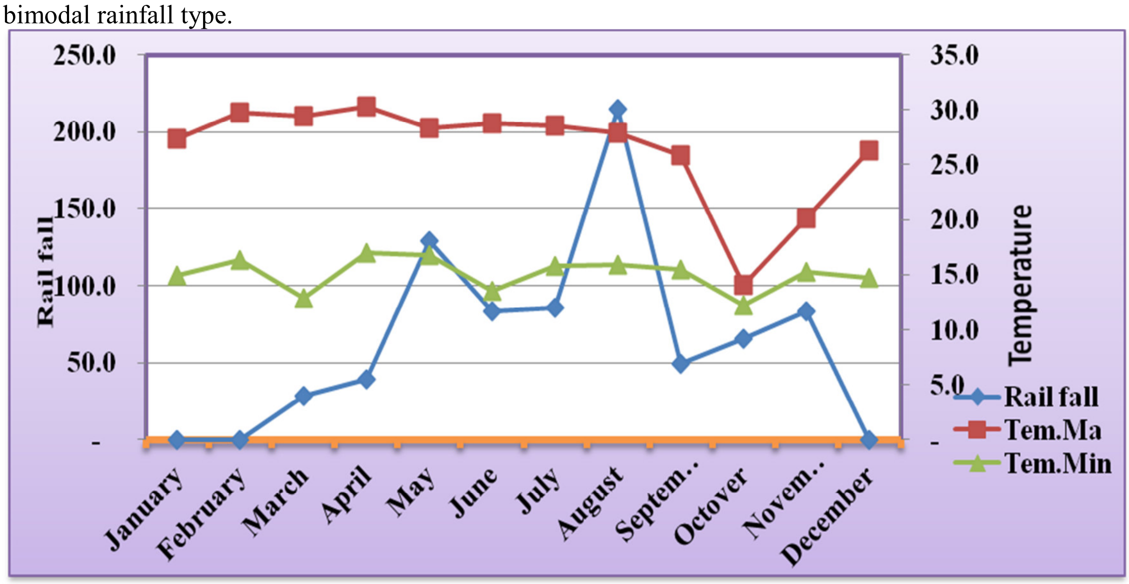


Figure 2. Rain fall and Temperature data of Arsi Golelcha District, 2015 GC

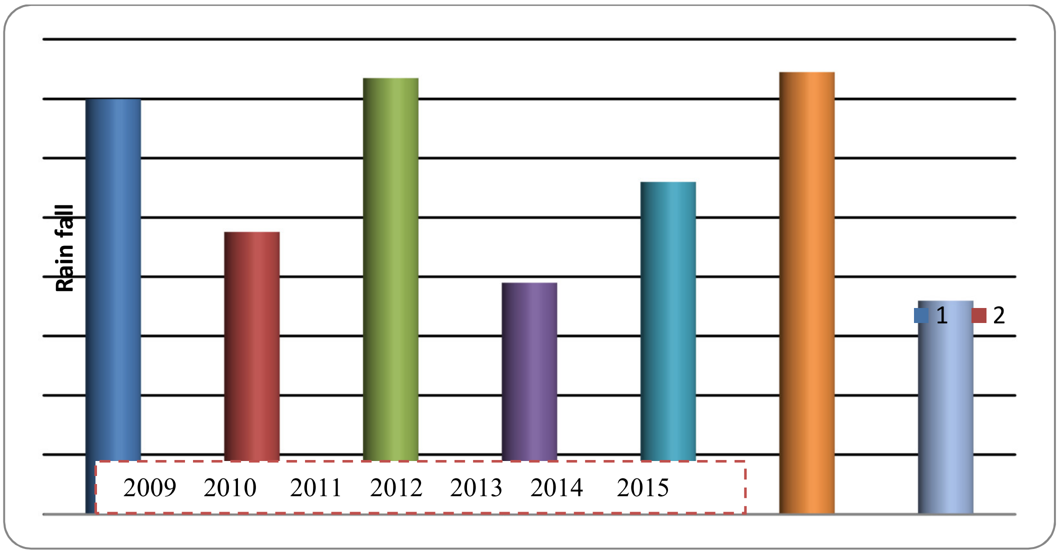


Figure 3. Seven years (2009-2015) Rain fall data of Arsi Golelcha District
(Source: Metrology station of Arsi Golelcha District)

2.1.3. Land use/land cover

Coffee is one of the main crops in the district. *Khat* and fruits are important cash crops. Out of the total area of the district, 20.6% is arable or cultivable, 21.7% is for pasture, 27% is covered with forest and shrubs, and the remaining 30.7% is considered swampy, mountainous or otherwise unusable. Golelcha has an estimated population density of 94.7 people per square kilometer. From a total area of 1,818.120 square kilometers, the general soil of the district cambi-sol which is the best for agricultural purpose (Oromia livelihood Profile, 2006).

2.2. Site Selection

The study was conducted in Golelcha District at two PA (Mine Golelcha/Jingadibu and Baqayisa/ Laftorifenso). From the selected PA, three villages were assigned from each PA. Then the study was under taken on three farmer's field from each village. To do this procedure, simple reconnaissance survey was applied in order to select villages and farmer's field for further analysis. The farmer's field was taken, as a representative across PAs over location with similar management practice; elevation and slope were considered for both unshaded and shaded coffee plantations.

2.3. Data to be collected

Data of coffee density under each shade tree species based on canopy coverage were counted. Data of coffee production: physical coffee yields such branch/coffee plant; number of node/coffee branch; coffee fruit/node; thousand seed weight; dry yield of coffee/plant and clean coffee/hectare were collected. The number of coffee plants under each shade tree species, with nearly equal canopy influence, were counted and compared. Six to eight coffee plants under each shade tree's canopy coverage were observed.

2.4. Sampling and Processing Techniques

2.4.1 .Coffee Shade Trees Selection and counting coffee density under shade trees

Targeted shade tree species (*Cordia africana* and *Erythrina abyssinica*) having dbh ≥20cm size, height of ≥5m length, and the shaded and unshaded coffee plantation, which have similar branch and crown on the same gradient and elevation seven to ten years old and ≥ 3m height were selected purposively from three villages and three farmers' fields as replication for each PA.

2.4.2. Coffee beans sampling

Coffee plants which originated under shade influence and spread over the three distance layers, that are 1, 3 and 6m away from the shade tree trunk and those which originated out of shade influence 25m away from the trunk were selected respectively. Thus were four coffee plants in all (West, East North and South) direction of coffee plating areas at each distance layer (1, 3 and 6m) away from the shade tree trunk, and four unshaded coffee plants, 25m away from shade effects were purposively selected and assigned for sample collection.

The coffee trees were selected based on canopy coverage of the shade tree and proportionality of coffee bean with equal range of all shade trees to count and measure physical coffee yield. So that, six coffee branches were selected and marked from the lower, middle and upper stick branch from west and east directions for each sample coffee plants at each distance layer. The sampled branches were counted and the number of fruits per node per branch were identified, which had been used to estimates yields of coffee/plant and yield of coffee/ha. 5

kg of fully ripe coffee cherry beans were collected from one layer and taken to be as one coffee sample from each distance layer (Siles et al., 2010; Bote and Struik, 2011). The same procedure was followed for both shade tree species on each farmer's fields that eight coffee bean samples from one replication/ farmers' field under both shade tree species and twenty-four coffee bean samples from three farmers' field in one PA, and over all forty-eight coffee bean samples were collected across PAs, respectively. The harvested coffee bean was dried until a constant moisture content of 12%. Dry coffee beans were weighted using digital measuring balance on basis of 1000 seed weight from shaded and unshaded coffee plants under each shade tree species from each study area of farmers' field in each distance layers from each coffee bean samples (Siles et al., 2010; Bote and Struik, 2011).

2.4.4. Coffee cherries drying process

The oldest and simplest method producing' natural' coffee is 'sun drying' that has been adopted throughout all coffee growing areas in Ethiopia, and in Arsi Golelcha 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.

2.5. Sample Procedure and Experimental Design

The design was arranged with factorials in (RCBD) for coffee samples' parameters by three replications for each treatment. Two shade tree species and four distance layers under each shade tree were taken as treatments of the study. The coffee sample parameters: coffee density under shade and physical coffee yield.

2.6. Data Analysis

Coffee density under the shade canopy and physical coffee yield's parameters were compared between shaded and open areas effect as well as between shade tree species effect. Then, the results of coffee parameters were analyzed by statistical software in order to get mean value difference.

Generally, analysis of variance (ANOVA) was done to determine differences among the mean of the treatments (between tree species and between shaded and unshaded parts of the results) with respect to coffee parameters through SAS software program (SAS, 2002 v.9.1) following the General Linear Model (GLM) procedure. The means that showed significant differences in F-test were separated by least significant difference (LSD) at (0.05 and 0.01) level, which used to multiple comparison procedures (Zar, 1996).

3. RESULTS AND DISCUSSIONS

3.1. Effect of Shade Tree Species and Distance from Tree Trunk at Physical coffee production in yield aspects

***A*. Influence of tree species and distance from tree trunk in Branch/coffee plant**

(*A=Available of branch per coffee plant: It was found by counting the sampled coffee branch)*

Significant comparisons at t-Test (0.05) level observed between both shaded coffee's effect, and also significant comparison between both shaded and unshaded coffee's effect for almost all coffee parameters likewise across PAs (Table 3).

The result of branch/coffee plant under the shade tree canopy showed highly significant variation ($P<0.01$) between shade tree species and between distance layers effect in Laftorifenso PA. In Jingadibu PA, on the contrary, available branch/coffee plant showed highly significance variation ($P<0.01$) between shade tree species and significance variation ($P<0.05$) between distance layers, correspondingly (Table 2).

The highest mean value of branch /coffee plant was observed at the 2nd distance layer under both shade tree species effect but the least mean value of branch/coffee plant was seen under unshaded coffee plants in JingadibuPA (Table 1). In Laftorifenso PA, the highest mean value of branch/coffee plant was observed at the 3rd distance layer under Cordia africana shade tree effect, while under *Erythrina abyssinica* shade tree effect, it was at the 2nd distance layer. The least mean value of branch/coffee plant was at unshaded coffee plant (Table 1). However; the variation on available branch/coffee plant in the given distances from the shade tree trunks under the canopies were visible between shaded and unshaded branches of coffee plant 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. The vital point to be considered in this result was the effect of shade trees may influencing normality of coffee branches from branch dieback disease, over bearing of fruits and long life expectancy of coffee plants that comes from unfavorable micro and macro climatic condition.

***B*. Influence of tree species and distance from tree trunk in number of node /coffee branch**

(*B=The number of node per coffee branch: it was found by counting number of node /branch)*

In this study, the available number of node /coffee branch was observed to have a highly significant difference ($p<0.01$) between tree species and between distance layers from shade trees' trunk towards open area across PAs (Table 2).

The highest value on the number of node /coffee branch in a given parameter was found at 2nd distance layer under both shade trees species, whereas the lowest value of the number of node/coffee branch found at the 4th distance layer, which was out of shade tree influence in JingadibuPA. In Laftorifenso PA, the highest value of node/coffee branch was observed at 2nd distance layer under *Cordia africana* shade tree, while under *Erythrina abyssinica* shade tree, the highest value of a given treatments' parameter was displayed at 2nd and 3rd distance layers, and the lowest value of treatments' parameter was displayed at the end distance layer that was out of shade trees' influence (Table 1).

Different researchers suggested the following idea, pertaining to coffee productivities. For example, Cannell (1975) suggested that close spacing of coffee bushes resulted in mutual shading that may inhibit floral initiation at existing nodes on coffee branches. Castillo and López (1966) reported fewer coffee flowers under shade than in full sunlight. Using artificial shade treatments, Montoya *et al.* (1961) found significant increases in the number of node per coffee branch and flower buds per node as sunlight level was increased. Montoya *et al.* (1961) also reported a significant positive correlation between the increases in the number of node per branch and yield per bush.

In general, the variation in available number of node /coffee branch between shaded and unshaded part of coffee plant was fairly reasonable as the higher contents of organic matter under the tree canopies due to higher accumulation of the litter falls, dead roots from the shade tree and protected from unfavorable micro and macro climatic condition to the shaded coffee plants. However; variation within distance under the shade tree canopy, might be because of shade concentration effect in which a recommended shade optimize transmission of light intensity unless and other wise, extreme abundance of shade utilization creates avoidance of bearing in coffee fruit as well as overall physiological fitness in coffee production (Beer *et al*., 1998).

C.* Influence of shade tree species and distance from tree trunk in number of coffee fruits /node (*C=number of fruit/node: it was found by counting number of fruits /node)

The available number of coffee fruit /node showed highly significant difference ($p<0.01$) between shade tree species and between distance layers from shade trees trunk in Laftorifenso PA, where as in Jingadibu PA, it showed highly significant difference ($p<0.01$) between shade tree species only. The highest value on available number of coffee fruits /node was observed under both shade trees' canopy at the 2nd distance layer, while the lowest value on available number of coffee fruits /node was observed at the end distance of the layers in unshaded coffee plant in Laftorifenso PA. In JingadibuPA, the highest value of the given treatments' parameter was displayed at the 2nd and the 3rd distance layers under both shade trees' influence while the lowest value of the parameter was observed at the end distance layer in unshaded coffee plant (Table 1). Cannell (1975) stated that the most important component of yield is the number of nodes formed. Therefore, it seems logical to conclude that, because both the number of nodes formed and the number of fruit set at each node can be affected by light levels, and shading on good site can directly reduce coffee yields even when all other growth factors are favorable.

D.* Influence of shade tree species and distance from tree trunk in all coffee fruits /coffee plant (*D=all coffee fruits/coffee plant: it was found that, D=AxBxC)

In this study, the available number of all coffee fruit /coffee plant revealed highly significance ($p<0.01$) differences between shade tree species and between distance layers' effect across PAs. The highest mean value of all coffee fruits /coffee plant was seen under both shade trees' canopy at the 2nd distance layers, while the lowest mean value was seen at the end distance layers in unshaded coffee plants across PAs (Table 1).

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 thoughts that higher shade density had a negative effect on coffee yield. Unshaded coffee needed higher input and it gave more yield than shaded plantations with the same management for a short sustain (Fournier, 1988; Chamorro et al., 1994). Nevertheless, trials in Costa Rica shaded coffee production yielded greater productivity than unshaded one that had been given the same management (ICAFE, 1989; Machado, 1999). However, shading by Calliandra species was reduced the yield by about 30% compared to the unshaded plots. In another experiment Machado (1999) indicated that production of unshaded treatment for Bourbon also revealed much lesser degree than shaded treatments but production of unshaded coffee plots diminished from year to year. However, some studies had demonstrated that higher yields can be obtained from intensively managed unshaded coffee but the results were inconsistent, probably because of widely varying site conditions and management. When comparing shaded versus unshaded coffee or comparing different shade species, a group of factors vary rather than just the factor 'species (Somarriba *et al.,* 1996).

In this study, the variation in available "all coffee fruits /coffee plant" with distance from the shade trees canopy was quite logical as a result of the above reasons. Beside, another point to be considered was, shade make a coffee to persist coffee fruit bearing condition with sustainable manner.

E.* Influence of shade tree species and distance from tree trunk in 1000 seed weight (*E=thousand seed weight in g: it was found by measuring 1000 seed of dry coffee fruits)

The study revealed that available '1000 seed weight in gm' showed highly significance difference ($p<0.01$) between shade tree species, while significance difference ($p<0.05$) observed between distance interval away from the shade tree trunks across PAs (Table 2). The highest mean value of 1000 seed weight in gram was observed at the 1^{srt} and 3rd distance layers under both shade trees species' influence, while the lowest mean value of the given parameters also observed at the end distance layers across PAs, respectively (Table 1).

According to Ebisa (2014) report, there was an observed relatively higher coffee weight (g/1000 bean) in shaded zone than in unshaded zone of coffee farms even if the difference was not statistically significant. Finding of Geromel *et al.* (2008) indicated that coffee weight was significantly higher in shade zone. Earlier study of Muleta *et al.* (2011) from south west Ethiopia was also confirmed higher coffee yield from shade grown. Contrarily, coffee bean yield was reported to be relatively higher in unshaded coffee zone (Bote and Struik, 2011).

The variation in available 1000 seed weight in gm with distance difference from shade tree trunk towards open area was inversely relationship with 'all coffee fruit /coffee plant' results. For example, the 2nd distance layer of shaded coffees' result was showed the highest yield of /coffee plant than the 1^{srt} and 3rd distance layers' coffee results under both shade tree species across PAs. This happen may be due to the highest bearing of coffee fruit consumed the highest amount of nutrient availability from the soil in order to nourish its fruits. Therefore, 1000 seed weight of highest coffee fruit yielder distance was showed the least 1000 seed weight results (Table 1).

F*. Influence of shade tree species and distance from tree trunk in dry yield weight/ coffee plant in kg (F=Dry yield of /coffee plant in kg: it was found, F=DxE÷1000)*

The rate on available of 'dry yield weight/ coffee plant in kg' observed highly significance difference ($p<0.01$) between shade tree species and significance difference ($p<0.05$) observed between distance layers from the shade tree trunk towards open area ($p<0.05$) in Laftorifenso PA. In Jingadibu PA, available of dry yield weight/ coffee plant in kg showed highly significance difference ($p<0.01$) between shade tree species and between distance layers away from the tree trunks to open areas (Table 2).

The highest mean value of dry yield weight/coffee plant in kg was observed under both shade trees species effect at the 2nd distance layers, while the lowest mean value of the given parameter was displayed at the end distance layers in unshaded coffee plants across PAs (Table 1). More or less the variation under the shade trees indicated the recommended distance of coffee plants to be planted that is, the 2nd distance layer away from the shade tree trunks. Therefore, coffee plants to be planted have to be at 2nd distance layer unless and other wise, if less than 3m or greater than 3m distance away from the shade tree trunks, the expected yields became decreased (Table 1). In this result to be estimated is, above ground or below ground biomass of shad tree effect. So that to identify such problems, it needs farther research investigation rather than liters fall accumulation under the shade trees canopy.

Despite the common belief that coffee produced under shade was higher quality that reported by Willey (1975). The report pointed out that although light may cause decrease etiolating and changes in leaf morphology and the chemical constituent of fruits. The report was concluded that shade could be affected the value of a vegetative products mainly and considerably on coffee beans weight effects. According to Hernández (1995) reported that even though insignificant differences between bean sizes of shaded and unshaded coffee plots; during two consecutive years of experiment, the conversion factor for dried beans per unit weight of green cherries under shaded coffee was greater than unshaded one. The other investigation accounted by Guyot *et al.* (1996) was, shade have positive effects on coffee bean weight and the chemical parameters which determine quality because shade enable coffee beans made slow ripening.

Generally, the shade intensity affected directly on the available of physiological health of coffee plants such as coffee beans, branch, leaves etc.

***G.* Influence of shade tree species and distance from tree trunk in clean coffee yield /hectare** *(G=clean coffee yield/ha in ton: that, G= F x 2.6 x 0.417- thus (2.6 value is conversion factor of dry cherries to red cherries and 0.417 value is conversion factor of red cherries to clean coffee)*

The available of clean coffee yield /hectare in ton value observed highly significant difference ($p<0.01$) between shade tree species across PAs and significant difference ($P<0.05$) observed between distance layers only in Laftorifenso PA. In Jingadibu PA, highly significant difference ($p<0.01$) observed between shad tree species and between distance (Table 2). The result of this study was based on the conversion factor of red cherries for dried beans per unit weight of green cherries in the available clean coffee yield /hectare in qtl that showed in (value=0.417 is conversion factor of red cherries to clean coffee). The highest mean value of a given treatments' parameters was observed at the 2nd distances layers under both shade trees species, while the lowest mean value of a given treatments' parameter was also observed at the end distance layers across PAs (Table 1).

The mean value difference, in available of clean coffee yield /hectare in tone, between treatments effect was displayed sensibly with logic of dry yield weight/ coffee plant in kg by reasonable hypothesis of conversion factor. The reasonable suggestion was taken based on the yield had been gained by correction factors in (Table 1) results. According to Hernández (1995) report specified that the conversion factor for dried beans per unit weight of green cherries was 0.6% higher under shaded than open one, which translated in to an additional 44 kg ha–1 of processed coffee.

Table 1. Effect of Shade Tree Species and Distance from Tree Trunk on physical Coffee yield under *Cordia africana* and *Erythrina abyssinica* shade trees in coffee fields at Laftorifenso and Jingadibu PA, Golelcha District, East Arsi zone.

Treatments		Laftorifenso PA Mean* ± Std							Jingadibu PA Mean* ± Std						
Tree species	Distance (m)	branch/coffee plant	No. of node /coffee branch	number of coffee fruits /node	all coffee fruits /coffee plant	1000 seed weight in gm	dry yield weight/coffee plant in kg	clean coffee /hectare in tone	branch/coffee plant	No. of node /coffee branch	number of coffee fruits /node	all coffee fruits /coffee plant	1000 seed weight in gm	dry yield weight/coffee plant in kg	clean coffee /hectare in tone
Cordia africana	1m	141±0.3	13±2.9	14±2	28,380±8.7	441±2.0	13±4.1	1.4±4.6	179±1.1	9±1.2	12±1.1	21,500±5.4	444±1.8	10±2.6	1.0±0.3
	3m	150±0.4	15±1.8	16±0.7	33,850±5.9	438±1.6	15±2.9	1.6±3.3	182±0.7	11±14	13±0.4	25,800±4.6	440±1.3	11±2.4	1.2±0.3
	6m	151±0.3	14±1.8	15±0.7	31,620±5.2	441±0.9	14±2.4	1.5±2.5	177±0.5	10±07	13±1.6	23,100±4.4	444±1.4	10±2.2	1.1±0.2
Without-T	25m	137±0.2	12±1.8	13±0.7	21,870±4.7	404.1±7	9± 1.9	1.0±2.3	151±0.5	9 ±0.9	10±0.8	15,600±2.8	417±0.6	7±1.1	0.7±0.1
Erythrina abyssinica	1m	152±0.3	15±1.9	15±0.8	33,240±6.2	457±1.8	15±3.2	1.7±3.6	186±1.2	10±15	13±1.4	26,000±5	468±2.0	12±2.5	1.3±0.3
	3m	153±0.4	16±0.9	16±0.3	38,710±3.4	454±1.5	18±1.9	1.9±2.3	189±0.7	12±17	14±0.7	30,300±4.2	464±1.5	14±2.3	1.5±0.2
	6m	150±0.2	16±0.8	15±0.3	36,480±2.7	457±0.8	17±1.4	1.8±1.5	184±0.5	11±09	14±1.9	27,600±3.9	468±1.6	13±2.2	1.4±0.2
Without-T	25m	139±0.2	12±0.8	13±0.3	26,730±2.2	420±0.6	12±0.9	1.3±1.4	165±0.6	9±1.2	11±1.1	20,200±2.3	441±0.8	9 ±1.0	1.0±0.1
LSD(0.05)		0.3	1.4	0.6	3.7	1.1	1.7	2.1	0.7	0.8	1.3	1.8	0.7	0.8	0.8
CV (%)		1.7	8.6	3.2	10.6	2.1	11.4	12.6	3.2	6	8.8	6.8	1.3	6.9	6.2

Note: Without-T= without shade trees

Table 2:Mean values on (*coffea arabica L.)* as influenced by distance from the trunk of *Cordia africana* and *Erythrina abyssinica* shade trees in coffee fields at Laftorifenso and Jingadibu PA, Golelcha District, East Arsi zone.

Parameters	Shade trees	Laftorifenso PA					Jingadibu PA				
		Distance from shade tree trunks				Open area	Distance from shade tree trunks				Open area
		1m	3m	6 m	MVD		1m	3m	6 m	MVD	
Brnch in no.	*C. africana*	140	150	151	147	137	179	182	177	179.33	158
	E. abyssinica	152	154	153	153	139	186	189	184	186.33	165
	*Mean**	146b	152a	152a	150	138c	183b	186a	181b	182.83	162c
Nfpnd in no.	*C. africana*	13	15	14	14	12	9.00	11.00	10.00	10.00	9.00
	E. abyssinica	15	16	16	16	13	10.00	12.00	11.00	11.00	9.00
	*Mean**	14ab	15^a	15^a	15	12c	10c	12a	11b	10.50	9.00c
Ftpnd in no.	*C. africana*	14.00	16.00	15.00	14.67	13.00	12.00	13.00	13.00	12.67	10.00
	E. abyssinica	15.00	16.00	15.00	15.33	13.00	13.00	14.00	14.00	13.67	11.00
	*Mean**	15b	16a	15b	5.00	13c	13a	14a	14a	13.17	11b
Alfrt in no.	*C. africana*	28380	33850	31620	31,283	21870	21,500	25,800	23,100	23,466.67	15,600
	E. abyssinica	33240	38710	36480	36,143	26730	26,000	30,300	27,600	27,966.67	20,200
	*Mean**	30810c	36280a	34050b	33,713	26730d	23,750c	28,050a	25,350b	25,716.67	17,900d
Sdwt in no.	*C. africana*	440	447	440	442.33	400	444.00	440.00	444.00	442.67	417
	E. abyssinica	457	454	456	455.67	420	468.00	464.00	468.00	466.67	441
	*Mean**	448.5a	450.5a	448a	449.00	410b	456a	452a	456a	454.67	429b
Dycpt in no.	*C. africana*	13.00	15.00	14.00	14.00	9.00	10.00	11.00	10.00	1.03	0.70
	E. abyssinica	15.00	17.00	17.00	16.33	12.00	12.00	14.00	13.00	1.30	0.90
	*Mean**	14.00c	16.00a	15.50b	15.17	10.22d	11c	13a	12b	1.17	0.8d
Clnc in no.	*C. africana*	1.40	1.60	1.50	1.50	1.00	1.00	1.20	1.10	11.00	7.00
	E. abyssinica	1.600	1.90	1.80	1.77	1.30	1.30	1.50	1.40	14.00	10.00
	*Mean**	1.50c	1.75a	1.65b	1.63	1.10d	1.2c	1.4 a	1.3b	12.50	9 d

Table 3: Comparisons between shade trees effect as well as between shaded and unshaded effect in the value of coffee parameters at t-Test (0.05) significance levels at the study area indicated by ***

Coffee parameters	Tree Comparison	Laftorifenso PA		JingadibuPA	
		Difference between Means	95% Confidence Limits	Difference between Means	95% Confidence Limits
Brnch in no.	*Ert----- Cor*	0.50	0.2594 - - 0.7406***	1.40	0.8531 - - 1.9469***
	Ert----- not	3.00	2.7310 - - 3.2690***	5.00	4.3886 - - 5.6114***
	Cor---- not	2.50	2.2310 - - 2.7690***	3.60	2.9886 - - 4.2114***
Nfnd in no.	*Ert----- Cor*	3.3333	2.1791 - - 4.4875***	1.5556	0.9243 - 2.1868***
	Ert----- not	6.3333	5.0429 - - 7.6238*	2.5556	1.8498 - - 3.2613***
	Cor---- not	3.00	1.7096 - - 4.2904***	1.00	0.2942 - - 1.7058***
Ftpnd in no.	*Ert----- Cor*	0.6667	0.2140 - - 1.1194*	2.00	0.9545 - - 3.0455***
	Ert-----not	3.3333	2.8272 - - 3.8395*	6.00	4.8311 - - 7.1689***
	Cor---- not	2.6667	2.1605 - - 3.1728*	4.00	2.8311 - - 5.1689***
Alfrt in no.	*Ert----- Cor*	9.727	6.681 - - 12.774***	9.0646	7.5851 - - 10.5440***
	Ert----- not	23.699	20.292 - - 27.105***	20.1473	18.4933 - - 21.8014***
	Cor---- not	13.971	10.565 - - 17.378***	11.0828	9.4286 - - 12.7368***
Sdwt in no.	*Ert----- Cor*	3.1778	2.2674 - - 4.0881***	4.80	4.2202 - - 5.3798***
	Ert----- not	8.7333	7.7155 - - 9.7511***	7.5667	6.9185 - - 8.2149***
	Cor---- not	5.5556	4.5378 - - 6.5734****	2.7667	2.1185 - - 3.4149***
Dycpt in no.	*Ert----- Cor*	5.3889	3.9598 - - 6.8180***	5.3667	4.6909 - - 6.0424***
	Ert----- not	12.2778	10.680 - - 13.8756***	10.1944	9.4390 - - 10.9499***
	Cor---- not	6.8889	5.2911 - - 8.4867***	4.8278	4.0723 - - 5.5833***
Clnc in no.	*Ert----- Cor*	0.5878	0.4171 - - 0.7584***	0.5667	0.5015 - - 0.6319***
	Ert----- not	13.1722	11.2644 - - 15.0801***	11.1056	10.3765 - - 11.8346***
	Cor---- not	7.2944	5.3866 - - 9.2023***	5.4389	4.7099 - - 6.1679***

*Note: for table 2 and 3 definition; ***= is significance and highly significance difference; Ert-- Cor= comparisons of Cordia africana with Erythrina abyssinica results; Cor-- not= comparisons of Cordia africana with without shade results. Brnc =branch/coffee plant; Nfnd=number of node/coffee branch;* Alfrt=all coffee fruit/ coffee plant; *Frtprnd= coffee fruit/node; Sdwt=thousand seed weight; Dycpt=dry yield of coffee/plant; Clnc =clean coffee/hectare.*

4. CONCLUSIONS AND RECOMMENDATIONS

Ethiopia is agricultural dependent based on seasonal rain fall chancellor. The pressure from rapidly growing human population has been directly and indirectly shrinking welfare natural resources. Deliberate growing of shade trees on farmlands, it is an agroforestry practice, to sustain environmental biodiversity, production and well ecological condition. However, coffee productivity under this system has not been comprehensively evaluated and properly documented. Indigenous coffee shade tree species, namely 'Erythrina abyssinica and Cordia africana' were carried out on six farmers' field across PAs in order to investigate the given treatments' parameters.

In the implementation of shade trees, *Erythrina abyssinica* was found to have higher significant value than *Cordia africana* shade tree with almost all coffee parameters from a given results; however the dominance of the species in the coffee farm was mainly because of its economic value, farmers preferred *Cordia africana* rather than ecological services. It covered about 60% and 48% of farm-land in Laftorifenso and Jingadibu PA while *Erythrina abyssinica* covered about 23% and 26% of farm-land in Laftorifenso and JingadibuPA, respectively.

Almost all the given coffee parameters' value increased significantly under the tree canopy than in the open area in both PAs showing decreasing trend with increasing distance from the tree trunk. The nearest and the farthest distance layers' result was indicated less than the 2nd layer in most parameters of treatments. The variation of layers' outcomes may be due to accumulation of litter falls intensity as the distance increased from the shade tree trunks and also may be due to capability of lateral roots consumed the litter falls as the distance decreasing from the shade tree trunks.

In a conclusion, Golelcha's District coffee farm land features deserved a certification as farmers' integration of coffee with shade can lead to be initiator of sustainable agriculture, organic coffee producer and promoter of climatic resilience. It needs such a certification because it can show how other farmers can be resilience to climate change and improved their livelihoods and because the practice can provide substantial ecosystem services. As many writers expressed, that certification approach should be advanced for organic coffee growers and fair traders had to be provided different price premium which can be offer farmers distinct economic incentives so that farmers may have a unique ecological welfare and organic output producer standards in order to sustain progressively. Coffee obviously has the highest share in a country such as Ethiopia's GDP and coffee growers should be motivated and their environmentally friendly practice or technology need to be demonstrated to farmers in other district of Hararghe or part of Ethiopia.

Successively across PAs, in almost all parameters, the best results were at the 2nd distance layer (3m) away from the shade tree trunks. This layer was designated to have better effect than the other layers under all coffee parameters' results. Based on the investigated effect of treatments, it can be recommended that remarkable distance of coffee seedling plating area is 3m away from the shade tree trunks under both shade tree species. However; *Cordia africana* was prevalent shade tree over most part of coffee fields, the empirical data obtained that the best result was found in most parameters of coffee production under *Erythrina abyssinica* shade tree species across PAs. Therefore, *Erythrina abyssinica* shade tree was the more recommended than *Cordia africana* shade tree based on the given results.

Convenience of shade tree which was currently being practiced in the area significantly improved coffee production, soil fertility and livelihood of the people. Therefore, the trees integration in the farming system is valuable and should be promoted by relevant stakeholders to be regarded as exemplar for farmers in neighboring districts who had been producing coffee without shade. This practice should be promoted in most districts of Hararghe that where coffee farmlands nearly wiped out and have been replacing with Khat. Although the present study indicated that a substantial contribution of coffee shade trees to coffee production improvement, this could not be an end in itself. Much more research work needs to be done in the following hesitation area of research potential:

Determinations of Erythrina abyssinica feeding habit (crude proteins and total digestible nutrients) have to be identified for sustainable animal production. Studies regarding the micro floral population associated with coffee shade trees such as Rhyzobia species and mycorrhizal fungal associations are of principal importance under the shade tree strength if being correlated with them. The root architectures of tree and photosynthesis variation needs better investigation due to shade intensity effect.

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figure 1: When physical yield of coffee plant data had been recorded for interpretation