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Sensory Attributes of Coffee under Different Shade Regimes and Levels of Management

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Abstract
Despite coffee bean physical and beverage quality attributes being inherent factors, the environment, which includes crop management factors, can play a major role in determining their expression. This study was conducted to evaluate the effect of management and shade levels on beverage quality of coffee. The study was carried out at the Kenya Agricultural and Livestock Research Organization, Coffee Research Institute (KALRO-CRI) farm in Bungoma County, Kenya. The coffee management levels were categorized depending on field operations and application of inputs. The different shade levels were based on the distances from the trunk of shade tree and shading levels were estimated by measuring the Photosynthetic Photon Flux Density (PPFD) in µmol m-2 s-1 using a Line Quantum Sensor. The sensory characteristics fragrance/aroma, flavor, aftertaste, acidity, body, balance and overall were assessed by a panel of seven trained judges. The beverage quality, except for acidity and balance, were largely unaffected by management or shade levels, however trends showed that most of the variables, on average, had higher scores in shade than in full sun. Shade was positively correlated with all sensory variables while management was negatively correlated with all. This suggested that use of shade, under low management, could offset the limited application of external inputs to some extent.
Keywords: *Coffea arabica*, shade, management levels and quality

1. Introduction

Coffee beverage quality, which is intimately related to its taste and aroma, is an important attribute of coffee that generates consumer satisfaction (Muschler 2001; Petracco 2001; Agwanda *et al*. 2003; Chalfoun *et al*. 2013). It is also often referred to as cup or liquor quality and is used as a measure for price determination (Gichimu *et al*. 2012). The beverage quality is based on the characterization of numerous factors such as fragrance and aroma, flavour, aftertaste, acidity, body, balance, overall and total score (Kathurima *et al*. 2009). Coffee beverage quality is assessed organoleptically (organoleptic relates to attributes perceptible by the senses) by trained coffee tasters (van der Vossen 1985; Agwanda 1999). There has been an emergence of a market for quality coffee which explains the increasing interest in research on environmental factors and local production systems that affect quality (Avelino *et al*. 2007). The international markets are also increasingly indicating demand for quality–differentiated coffee (Oberthur *et al*. 2011). The market success of the international specialty coffee industry, including rapidly increasing numbers of small to medium roasters of high quality coffee beans and several chains of upmarket coffee houses provide evidence that consumers are more discerning about beverage quality and are willing to pay for it (Pendergrast 1999).

A coffee tree in good growing conditions tends to produce larger beans with better flavour (Wintgens 2004). Climate, altitude, and shade have a strong influence on flowering, bean expansion, and ripening through their effect on temperature, availability of light and water (Carr 2001; Decazy *et al*. 2003). Shade, or conditions that provide lower air temperatures such as higher elevations slow down the ripening process of coffee berries allowing more time for complete bean filling (Vaast *et al*. 2006) resulting in bigger beans that are denser and far more intense in flavour than those grown under lower altitudes or under full sunlight. The slower maturation process, therefore, plays a central role in ensuring 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). Other authors (Muschler 2004; Geromel *et al*. 2008; Bote & Struik 2011; Somporn *et al*. 2012) have reported similar positive effects of shade on coffee bean size and beverage quality. Kathurima *et al*. (2012) recognized the significant contribution of the shade to the increased premium grades, AA and AB, which are highly valued in the coffee trade in Kenya but found no clear gain on the sensory quality parameters. Studies have also shown that different shade tree species affect the sensory quality differently. Shade also reportedly reduces the portion of rejects which include diseased, mummified or dried berries. In Costa Rica, Muschler (1998) reported that rejects accounted for up to 10% in the un-shaded samples and less than 1% under shade.

Excessive use of nitrogen, while it increases production, has been reported to reduce bean density and quality. In South America, Dessalegn (2005) reported that coffee grown with heavy application of nitrogen fertilizer had poorer, lighter and thinner body than that from unfertilized fields. A high concentration of calcium and potassium in beans has been associated with a bitter and “hard” taste while no correlation has been reported between phosphorus and the physical and organoleptic quality of the bean (Northmore 1965). A study by Foote (1963) showed that nutrient deficiencies may decrease cup flavour. On the other hand, Pochet (1990)

demonstrated a very clear and positive link between the organoleptic qualities and low soil fertility. Da Matta (2004) documented in his study of eco-physiological constraints of coffee that the benefits of shade increase as the environment becomes less favorable for coffee cultivation. This study was therefore, conducted to evaluate the effect of management and shade levels on beverage quality of coffee in Kenya.

2. Materials and Methods

2.1 Study site

This study was conducted at the Kenya Agricultural and Livestock Research Organization – Coffee Research Institute demonstration (KALRO–CRI) plot in Namwela and two surrounding small holder farms within the locality from year 2010 to 2012. Namwela is located in Bungoma County at 0º 45'43N 34º 33'42E, at an elevation of 1641 meters above sea level with an average rainfall of 1329 mm. The sites chosen had similar climatic and soil conditions due to their proximity. The three farms represented high, medium and low management level treatments.

2.2 Experimental design and layout

The experimental design was a split plot, with management level as main plot treatment and shade level as the sub-plot. The coffee variety in this study was K7 while shade was provided by *Cordia africana*. The management levels were categorized depending on field operations and externally applied inputs as described by Mugo (2010). Based on these criteria, a coffee plot under high management level was managed using all the recommended practices by Coffee Research Foundation (CRF 2013) for optimum production. Under medium management level, the external inputs applied included farm yard manure and inorganic fertilizers; and pesticides (insecticides and fungicides for the control of insect pests and diseases respectively). Under the low management level, there was no application of external inputs at all. The different shading levels were based on the distances from the trunk of the shade tree: 0 – 1.5 m (80%), 1.5 – 3 m (70%), 3 – 4.5 m (50%), 4.5 – 6 m (30%) and full sun (0%). The shading level was estimated by measuring the Photosynthetic Photon Flux Density (PPFD) in µmol m-2 s-1 using a Line Quantum Sensor (LI-COR Biosciences) and expressing it as a percentage of that obtained in full sun as described by Vaast *et al*. (2007).

2.3 Processing of coffee samples

Fully ripe coffee cherries were harvested from four trees in each of the five treatments in each site during the year 2010/11and 2011/12 coffee seasons. The cherries were bulked and wet processed using standard procedures (Mburu 2004). The cherry samples were pulped, fermented, washed and the wet parchment dried to final moisture content of 10.5 to 11%. The parchment coffee was hulled and graded based on size, shape and density (Gichimu *et al*., 2012) and grade AB was used for the subsequent analysis in the study.

2.4 Roasting and sensory evaluation

Roasting of green coffee was done to attain a medium roast using a Probat laboratory roaster within 24 hours of sensory evaluation and coffee allowed to rest for at least eight hours. Samples were weighed out to the predetermined ratio of 8.25g per 150 ml of water. Sensory evaluation procedure described by Lingle (2001) was followed. Fragrance/aroma, flavor, aftertaste, acidity, body, balance and overall were assessed and scored together with three process control parameters (uniformity, clean cup and sweetness) by a panel of seven trained judges on a 10-point scale. Balance is the assessment of how well the flavor, aftertaste, acidity, and body fit together in a synergistic combination. All the sensory parameters including the process control parameters were added to constitute the total sensory score which is a reflection of the broad quality performance of a particular coffee.

2.5 Data analysis

The sensory data obtained were subjected to analysis of variance at 5% level of significance using Costat version 6.400 (1998-2008, Co Hort Software) statistical program. Least significant difference (LSD) was used to separate the means. The computer program IBM SPSS Statistic 19 was used to perform statistical correlation analysis using Pearson Correlation Coefficients.

3. Results

The fragrance of coffee was significantly affected by management level in season 1 and by shade level in season 2 (Table 1). On average, shaded coffee had higher fragrance scores than coffee in full sun. In season 1, coffee under low management level had significantly higher scores for fragrance than that under medium management; however it was not different from coffee under high management. In season 2, management levels had no significant effect on fragrance.

Table 1: Fragrance and aroma of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.64	7.57	7.64	7.62	7.64	7.82	7.86	7.77
1.5 – 3.0	7.57	7.54	7.57	7.56	7.57	7.68	7.61	7.62
3.0 – 4.5	7.54	7.54	7.57	7.55	7.57	7.64	7.75	7.65
4.5 – 6.0	7.61	7.50	7.61	7.57	7.64	7.61	7.64	7.63
Full sun	7.46	7.46	7.54	7.49	7.43	7.57	7.54	7.51
Mean	7.56	7.52	7.59		7.57	7.66	7.68	
LSD (ML)	0.05				NS			
LSD (SL)	NS				0.11			
LSD (ML x SL)	NS				NS			
CV (%)	2.03				2.34			

Key: ML – Management level, SL – Shade level; Score: 1 = very poor and 10 = outstanding for fragrance; NS – Not significant at $p<0.05$

The flavour was affected by shade level in both seasons but the effect of management level was only significant in season 2. In season 1, shaded coffee had higherscores for flavor than that in full sun. Management level was only significant in season 2, where coffee under low management level had better scores than those under high and medium management levels.The interaction effect was not significant in both seasons (Table 2).

Table 2: Flavour of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management levels				Management levels			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.75	7.61	7.64	7.67	7.71	7.75	7.64	7.70
1.5 – 3.0	7.61	7.71	7.71	7.68	7.68	7.64	7.71	7.68
3.0 – 4.5	7.54	7.50	7.64	7.56	7.75	7.71	7.86	7.77
4.5 – 6.0	7.43	7.50	7.57	7.50	7.57	7.71	7.86	7.71
Full sun	7.43	7.46	7.54	7.48	7.50	7.57	7.57	7.55
Mean	7.55	7.56	7.62		7.64	7.68	7.73	
LSD (ML)	NS				0.05			
LSD (SL)	0.12				0.1			
LSD (ML x SL)	NS				NS			
CV (%)	2.67				2.29			

Key: ML – Management level, SL – Shade level; Score: 1 = very poor and 10 = outstanding for flavor; NS – Not significant at $p<0.05$

The after taste was not affected by either the management or shade levels in both seasons (Table 3).

Table 3: After taste of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.71	7.54	7.61	7.62	7.68	7.54	7.64	7.62
1.5 – 3.0	7.57	7.61	7.64	7.61	7.61	7.68	7.71	7.67
3.0 – 4.5	7.61	7.46	7.54	7.68	7.68	7.61	7.82	7.70
4.5 – 6.0	7.61	7.54	7.54	7.57	7.57	7.57	7.71	7.62
Full sun	7.50	7.50	7.57	7.52	7.43	7.71	7.68	7.61
Mean	7.60	7.53	7.58		7.59	7.62	7.71	
LSD (ML)	NS				NS			
LSD (SL)	NS				NS			
LSD (ML x SL)	NS				NS			
CV (%)	2.34				2.81			

Key: ML – Management level, SL – Shade level; Score: 1 = very poor and 10 = outstanding for aftertaste; NS – Not significant at $p<0.05$

The acidity of the coffee was affected significantly ($p<0.05$) by shading levels in both seasons. However, management levels had no significant effect. Shaded coffee tended to have higher acidity, on average, than coffee in full sun. There were no significant interactions in both seasons (Table 4).

Table 4: Acidity of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.75	7.71	7.86	7.77	7.79	7.61	7.64	7.68
1.5 – 3.0	7.71	7.61	7.71	7.68	7.79	7.82	7.79	7.80
3.0 – 4.5	7.79	7.64	7.68	7.70	7.86	7.82	7.89	7.86
4.5 – 6.0	7.79	7.71	7.86	7.79	7.61	7.79	7.89	7.76
Full sun	7.57	7.54	7.68	7.60	7.57	7.75	7.71	7.68
Mean	7.72	7.64	7.76		7.72	7.76	7.78	
LSD (ML)	NS				NS			
LSD (SL)	0.1				0.09			
LSD (ML x SL)	NS				NS			
CV (%)	2.12				2.0			

Key: ML – Management level, SL – Shade level; Score: 1 = very flat and 10 = very bright for acidity; NS – Not significant at $p<0.05$

The effect of management and shade level on the body of the coffee beverage was not significant in all the seasons (Table 5).

Table 5: Body of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.68	7.54	7.64	7.62	7.61	7.71	7.68	7.67
1.5 – 3.0	7.64	7.61	7.54	7.60	7.75	7.64	7.71	7.70
3.0 – 4.5	7.57	7.57	7.61	7.58	7.68	7.68	7.79	7.72
4.5 – 6.0	7.64	7.75	7.71	7.70	7.68	7.61	7.75	7.68
Full sun	7.57	7.57	7.57	7.57	7.57	7.68	7.64	7.63
Mean	7.62	7.61	7.61		7.66	7.66	7.71	
LSD (ML)	NS				NS			
LSD (SL)	NS				NS			
LSD (ML x SL)	NS				NS			
CV (%)	2.73				2.24			

Key: ML – Management level, SL – Shade level; Score 1 = very thin and 10 = very heavy for body; NS – Not significant at $p<0.05$

The balance of the coffee beverage was significantly affected by the management levels in both seasons but the shade effect had no significant effect (Table 6). The low management level had higher scores on average than the medium and high levels.

Table 6: Balance characteristics of coffee beverage under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.64	7.54	7.61	7.60	7.61	7.61	7.68	7.63
1.5 – 3.0	7.54	7.57	7.64	7.58	7.57	7.64	7.68	7.63
3.0 – 4.5	7.54	7.54	7.61	7.56	7.61	7.61	7.71	7.64
4.5 – 6.0	7.46	7.50	7.61	7.52	7.54	7.64	7.68	7.62
Full sun	7.39	7.54	7.61	7.51	7.46	7.64	7.57	7.56
Mean	7.50	7.54	7.62		7.6	7.63	7.66	
LSD (ML)	0.1				0.1			
LSD (SL)	NS				NS			
LSD (ML x SL)	NS				NS			
CV (%)	1.9				1.9			

Key: ML – Management level, SL – Shade level; Score: 1 = very poor and 10 = outstanding for balance; NS – Not significant at $p<0.05$

The parameter 'overall' is meant to reflect the holistically integrated rating of the sample as perceived by the individual panelist.The overall score of the coffee beverage was not significantly affected by both shade and management level in season 1. However, effects of both were significant in the second season (Table 7). Coffee under the low management and medium levels had higher overall scores than high management levels. There was no significant difference in overall score between low and medium management levels. Shaded

coffee recorded significantly higher scores for the overall than full sun coffee. There was no significant difference on overall scores within the shaded coffee.

Table 7: Overall score of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	Mean	High	Medium	Low	Mean
0 – 1.5	7.54	7.50	7.64	7.56	7.64	7.71	7.86	7.74
1.5 – 3.0	7.61	7.54	7.68	7.61	7.71	7.71	7.75	7.72
3.0 – 4.5	7.46	7.50	7.54	7.50	7.75	7.64	7.86	7.75
4.5 – 6.0	7.43	7.61	7.61	7.55	7.54	7.64	7.86	7.68
Full sun	7.39	7.50	7.46	7.45	7.36	7.54	7.64	7.51
Mean	7.49	7.53	7.59		7.6	7.65	7.79	
LSD (ML)	NS				0.1			
LSD (SL)	NS				0.13			
LSD (ML x SL)	NS				NS			
CV (%)	2.28				2.92			

Key: ML – Management level, SL – Shade level; Score: 1 = very poor and 10 = outstanding for preference; NS – Not significant at $p<0.05$

On average, the total score which is a consideration of the general coffee quality performance showed that coffee under low management scored higher than that medium and high management. No interaction effect was observed for this score in both seasons (Table 8).

Table 8: Total sensory score (%) of coffee under different management and shade levels

Distance (m)	Season 1				Season 2			
	Management level				Management level			
	High	Medium	Low	**Mean**	High	Medium	Low	**Mean**
0 – 1.5	83.14	83.57	83.57	**83.43**	83.68	83.21	84.68	**83.86**
1.5 – 3.0	83.64	83.18	83.36	**83.39**	83.68	83.93	84.61	**84.07**
3.0 – 4.5	83.11	83.00	83.57	**83.23**	83.89	83.79	83.82	**83.83**
4.5 – 6.0	82.50	83.11	83.21	**82.94**	83.43	82.57	83.79	**83.26**
Full sun	82.29	82.71	83.00	**82.67**	82.32	82.54	83.46	**82.77**
Mean	**82.94**	**83.11**	**83.34**		**83.4**	**83.21**	**84.07**	
LSD (ML)	0.31				0.47			
LSD (SL)	0.48				0.66			
LSD (ML x SL)	NS				NS			
CV (%)	0.94				1.29			

Key: ML – Management level, SL – Shade level; NS – Not significant at $p<0.05$

3.1 Correlation among shade, management levels and sensory variables

Shade was positively and significantly correlated with acidity and body (Table 9). Positive but non-significant correlation was observed between shade and the other sensory variables, namely fragrance, flavour, aftertaste, balance and the overall score. Management level was significantly and negatively correlated with balance and the overall score. The correlation between management level and the other sensory variables were also negative but non-significant. All the sensory variables had significant and positive correlations between them except, that of fragrance and acidity whose correlation, while positive, was non-significant.

Table 9: Correlation coefficients of sensory variables showing effect of season, shade and management levels

Variables								
Shade	Shade							
Management	0.000	Management						
Fragrance	0.168	-0.291	Fragrance					
Flavour	0.217	-0.279	0.578**	Flavour				
Aftertaste	0.084	-0.236	0.482**	0.668**	Aftertaste			
Acidity	0.471**	-0.198	0.315	0.532**	0.661**	Acidity		
Body	0.394*	-0.152	0.504**	0.496**	0.526**	0.499**	Body	
Balance	0.122	-0.596**	0.650**	0.793**	0.703**	0.536**	0.439**	Balance
Overall	0.263	-0.458*	0.698**	0.774**	0.657**	0.536**	0.673**	0.781**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

Coffee is a beverage where flavor is the most important quality parameter and a major motivation for consumer preference (Clarke 1987; Cantergiani *et al*. 1999; Marin *et al*. 2008). In this study, coffee under *Cordia africana* shade had higher scores for flavor, acidity and total score than coffee in full sun. Similar findings were reported by Vaast *et al*. (2006; 2007) who found that positive attributes such as beverage acidity and preference were significantly higher for coffee produced under shade of timber trees. They further observed that negative attributes such as astringency and bitterness were higher for coffee beverage prepared from sun-grown beans. The delayed ripening between the berry pulp and bean caused by shade is proposed as one of the reasons explaining observed differences in beverage quality between shade-grown and sun-grown coffee.The delayed ripening leads to complete berry maturation that favors the development of high quality flavor in the coffee as postulated by Montavon *et al*. (2003).

Yadessa *et al*. (2008), working with different shade trees, demonstrated that coffee under *Acacia abyssinica* and *Cordia africana* shade produced coffee beans that were acidic, with better flavor than those produced under *Albizia schimperiana* and *Albizia gummifera* shade. In contrast, Bosselmann *et al*. (2009) reported that sensory attributes were negatively influenced by shade. They found that shade, at high altitude, had a negative effect on fragrance, acidity, body, sweetness and preference of the beverage. The conflicting results may be due to the different coffee cultivars and diversity of shade trees used in these different studies. The management levels had a significant effect on balance and total score in both seasons; however, the effect on fragrance, flavour and overall preference were not consistent being only significant in one season. Generally, coffee under low management levels had significantly higher scores for acidity, balance and total score in both seasons; it also had higher scores for fragrance in season 1, flavour in season 2 and overall preference than medium and high management levels. This observation was reinforced by the negative correlation between management levels and all sensory variables, with that between balance and overall being significant. Earlier studies by Amorim *et al*. (1973) showed that coffee beans harvested in plots where nitrogen and potassium were applied gave asignificantly lower quality beverage. Dessalegn (2005) demonstrated that coffee grown with heavy application of nitrogen fertilizer had poorer, lighter and thinner body than that from unfertilized fields. Cannell (1985) reported that yield had a negative effect on beverage acidity as a result of competition for carbohydrates among coffee berries during heavy production cycles. Similarly, Pochet (1990) found a clear and positive link between coffee organoleptic qualities and low soil fertility. Findings by Vaast *et al*. (2006) furthermore illustrated the antagonistic relationship between coffee tree productivity, bean size and quality. In contrast, Lara-Estrada & Vaast (2007) reported a positive influence of fertilization on the coffee bean size and organoleptic characteristics. The increase in bean size and weight resulted in higher fat accumulation and lower trigonelline concentration that led to a better aroma, flavor and overall score. Comparable results have been reported in other studies (Franca *et al*. 2005; Decazy *et al*. 2003). As Da Matta (2004) established, in his study of eco-physiological constraints of coffee, the benefits of shade increase as the environment becomes less favorable for coffee cultivation.

5. Conclusion

The results of this study show that the use of shade, especially under small holder, low input conditions that predominate in Kenya, can result in production of high quality coffee. The coffee under low management had, as good as or better scores for various sensory variables than those under medium or high management. Trends showed that most of the variables had better scores under shade than in full sun. All sensory variables were positively correlated with shade while they were negatively related with management levels. This suggested that use of shade under low management could probably offset none or limited application of external inputs.

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