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Influence of Coffee Production Systems on the Occurrence of Coffee Beans Abnormality: Implication on Coffee Quality

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ABSTRACT
In Ethiopia, coffee production system can mainly be categorized as; garden, plantation, semi-forest and forest coffee production systems which are assumed to vary in the intensity of management. But, little is known whether these production systems and the associated management practices have effect on coffee beans abnormalities. Besides, the role of pea berry on cup quality parameters has not been documented under Ethiopian condition. Therefore, the study was carried out to assess the influence of coffee production systems on the occurrence of bean abnormality and cup quality. The study was carried out in the landscape matrix of forest and agricultural lands near Jimma, in South-western Ethiopia. A total of 24 study sites in four production systems were sampled. Coffee cherries were prepared following the standard procedure for wet method of processing. The beans sensory quality was tested with and without pea berry (the major bean abnormality observed in this study). Coffee production system showed significant influence on the occurrence of bean abnormality. Plantation coffee production system showed significantly higher proportion of pea berry which accounts for higher portion of bean abnormality than the rest of production systems ($p<0.001$). There was no significant difference between the coffee beans tested with and without pea berry in all of the production systems except body in the garden coffee production system, where the coffee tested with pea berry gave the lower grade while coffee tested without pea berry scored the highest grade. In conclusion, an evidence was not generated for the negative effect of pea berry on coffee quality. However, future study was recommended on the causes of bean abnormalities in coffee across coffee production systems as occurrence of pea berry may have yield implication.

Key words: Bean abnormality, *Coffea arabica*, cup quality, production system, pea berry

INTRODUCTION

Coffee is the leading global beverage after water and its trade exceeds US$ 10 billion worldwide (Vega, 2008). Over 60 tropical and subtropical countries produce and export coffee, being for some of them the main agricultural export commodity (Vieira, 2008). Globally, over 100 million people derive their livelihood from coffee (Waller *et al*., 2007). The global coffee production depends only on two species, *Coffea arabica* and *C. canephora* (Anthony *et al.*, 2002; Labouisse *et al.*, 2008). Arabica or highland coffee (*C. arabica*) accounts for 2/3 of global coffee production and the remaining portion comes from *C. canephora* (Labouisse *et al.*, 2008). *Coffea arabica* is the only coffee species grown in Ethiopia and the country is the primary centre of origin and genetic diversity for this crop (Anthony *et al.*, 2002; Vega, 2008). Ethiopia is first producer and exporter in Africa and 5th in the world with the total production of 486,000 in 2012/2013 (ICO., 2013). Arabica coffee contributes 35% of the total export earnings, 25% of the employment opportunity and 10% GDP in Ethiopia (MARD., 2008; Gole and Senbeta, 2008).

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

Ethiopian farmers normally produce nine spectra of the finest single-origin/specialty coffees (Jimma, Nekemte, Illubabor, Limmu, Tepi, Bebeka, YirgaChefe, Sidamo and Harar) which are now well diffused into the trade circuits of the coffee industry (Mekuria *et al*., 2004). The world's best quality coffees such as Harar, Limu and Yirgacheffe are produced from the eastern and southwestern parts of Ethiopia (ITC., 2002). However, it is beyond dispute that in Ethiopia the quality of coffee produced by farmers has been deteriorating from time to time. At different forum, serious complaints have been raised about the declining quality of coffee produced in different parts of the country (Nure, 2008).

Genetic origin greatly influences coffee quality (Leroy *et al*., 2006). Comparisons of different varieties based on organoleptic evaluation and several scientific procedures indicate that similarities and differences are attributable to genetic traits (Ky *et al*., 2001; Puerta, 2000; Silvarolla *et al*., 2004). Bertrand *et al*. (2006) reported the effects of variety and elevation on cup quality. In addition to genetic factors, farmers management practices embedded within different production systems are also expected to affect the final quality of coffee beans. Similarly, Wormer (1964) described coffee beans abnormalities can occur due to genetic make-up of the plant itself or environmental factor or both. Generally, bean abnormalities include pea berry, triage, elephant bean, misshaped and empty beans (Wintgens, 2012). Abnormal fruit development resulting in abnormal and misshaped beans is not uncommon. An example of such an abnormally formed coffee bean is a "Pea berry". Pea berries occur when only one ovule matures and one is aborted during fruit development, resulting in one seed (Wintgens, 2012). Although pea berries are commercially generally undesirable due to their shape (deformed or misshapen), there is a niche market for them (Ricketts *et al*., 2004).

Coffee growers follow different management practices depending on the type of production systems they prefer to increase production and productivity of their crop. However, there was no single research conducted so far to exploit the role of production system on the occurrence of bean abnormality on the one hand and the effect of bean abnormalities on final coffee beans quality on the other hand. Therefore, the aims of this research were: (1) To evaluate the effect of production systems on the occurrence of abnormal beans in *C. arabica* and (2) To evaluate the effect of pea berry on coffee cup quality across production system in SW Ethiopia.

MATERIALS AND METHODS

Description of study sites: The study was conducted in Jimma region southwestern Ethiopia during the 2012/13 cropping season. The present study involved 24 study sites selected from two districts (Gera and Manna). Manna is located 20 km northwest of Jimma town while Gera is located at 70 km west-northwest of Jimma town. Jimma town is situated in the Oromiya region in the highlands of south west Ethiopia. The study area is situated between 1800 and 2100 masl. There is a humid, sub-tropical climate, with an yearly rainfall of about 1500 mm or more per annum, a short dry season and relatively high cloud cover. A peak in rainfall occurs between July and September (long rainy season) and a smaller peak occurs between March and April (short rainy season). Differences in temperature throughout the year are small with a mean minimum and maximum annual temperature of 11.9 and 26.4°C (Schmitt, 2006).

Sample collection, preparation and cup quality analysis: In each site, a sampling plot of 20×20 m was placed. The trees of middle aged were selected and red cherries were collected and transported to JUCAVM. Then cherries were wet processed (pulped, pre-washed, fermented, washed and dried on wire mesh). For all samples taken from different production system, 1 kg of red cherries was hand pulped to percent out the proportion of abnormal beans. After counting, they were mixed to the sample from where they were taken.

A total of 48 samples were taken for both physical and sensory evaluation. About 350 g sample were taken from each plot for further analysis with a total of 16,800 g. Cup test was examined based on roasted coffee analysis by which aroma, acidity, body and other flavor components was tested. Ethiopian Commodity Exchange (ECE., 2009) grading procedures were followed for physical and sensorial evaluation.

Experimental design: The experiment was laid out in 4×2 factorial in Randomized Complete Block Design (RCBD). Factor A was production system with four levels (garden, plantation, semi-forest and forest) and Factor B was bean type with two levels (normal and pea berry+normal bean).

Statistical analysis: For statistical comparisons among production systems, in terms of physical and organoleptic quality of coffee beans, first ANOVA model assumption were checked. The variables defect, shape and make, color, odor, cup cleanness, acidity, body, flavor and overall quality fulfilled normality assumptions and consequently a 4×2 factorial design was used to compare production systems with respect to different measures of test quality, followed by mean separation using a LSD test for significant response variables. All the analysis were performed using SAS Version 9.2.

RESULTS

Effect of production system on the occurrence of bean abnormality: Pea berry occurrence showed significant difference ($p<0.001$) among the production systems. The highest percentage (31.2%) of pea berry was found in the plantation coffee production system. The number of pea berry in the other production systems also numerically varies but not statistically significant. There was significant difference among the different production systems in bearing total bean abnormality which was highly contributed by pea berry (Table 1).

There were significant differences among production systems in terms of number of fruits comprising a kilogram and this value was the lowest for plantation and the highest for semi-forest (Table 1). This has an indication that cherry fruit weight is the highest for plantation as compared to the other production systems. This could be attributed to the optimum management rendered to coffee shrubs in plantation production system compared to the other systems where human management intensity is relatively low and use of modern inputs such as fertilizers and pesticides are not practiced. Triage percent was very low for all production systems and the total bean abnormality was largely defined by the pea berries.

Effects of pea berry on cup quality: There was no significant difference between the coffees tested with and without pea berry in all production system except body in the garden coffee production system. Coffee tested with pea berry scored the lowest grade whereas coffee tested without pea berry scored the highest grade (Table 2).

Effects of production systems on coffee quality: Generally, there were significant differences among the production system in relation to some cup and raw quality parameters. The significant effect of production system on defect was realized ($p = 0.04$); the lowest defect was found in the forest coffee production system but there was no significant difference between the rest of production system which shared the same latter. The highest grade of color was found in the forest coffee production system whereas the plantation and semi-forest coffee shared the same latter but it was the lowest (Table 3).

Correlation: Coffee bean type was not significantly correlated with most quality attributes assessed ($p>0.05$). Pea berry significantly and negatively correlated with acidity in plantation coffee production system ($R = -0.96$). Acidity was significantly and positively correlated with normal beans also in plantation coffee production system ($R = 0.93$) (Table 4).

Table 1: Occurrence of coffee bean abnormalities as influenced by different coffee production systems in SW Ethiopia

Production system	Total No. of fruits (kg^{-1})	Pea berry (%)	Triage (%)	Total abnormality (%)	Normal (%)
Forest	739 ± 40^{ab}	16.2^{b}	0.2 ± 0.1^{a}	18 ± 3^{ab}	82 ± 3^{ab}
Garden	791 ± 34^{a}	16.4^{b}	0.1 ± 0.0^{a}	16 ± 2^{b}	83 ± 2^{a}
Plantation	661 ± 15^{b}	38.8^{a}	0.0 ± 0.0^{b}	31 ± 9^{a}	69 ± 9^{b}
Semi-forest	824 ± 24^{a}	15.7^{b}	0.1 ± 0.0^{ab}	16 ± 2^{b}	84 ± 2^{a}
LSD	89.27	14.14	0.14	14.12	14.14

Values are taken as Mean±SD, Means followed by the same letter(s) along the column showed non-significant difference

Table 2: Effect of pea berry on physical and cup quality attributes of coffee beans grown under different coffee production systems in SW Ethiopia

	Raw analysis **				Sensorial analysis**				
Parameters	Defect 20 (%)	Shape and make	Color	Odor	Cup cleanness	Acidity	Body	Flavor	Overall
FCWPB	19.0^{b}	8.0^{a}	3.8^{a}	4.6^{a}	15^{a}	13.0^{a}	11.5^{ab}	12.5^{a}	87.7^{a}
FCWOPB	19.0^{b}	8.0^{a}	3.8^{a}	4.6^{a}	15^{a}	13.5^{a}	13.0^{a}	14.0^{a}	87.7^{a}
GCWPB	19.3^{ab}	7.7^{a}	3.2^{ab}	4.0^{a}	15^{a}	13.0^{a}	10.5^{b}	12.0^{a}	87.2^{a}
GCWOPB	19.3^{ab}	7.7^{a}	3.2^{ab}	4.0^{a}	15^{a}	13.5^{a}	12.5^{a}	13.0^{a}	87.2^{a}
PCWPB	20.0^{a}	8.0^{a}	3.7^{b}	3.5^{a}	15^{a}	13.5^{a}	12.0^{a}	12.5^{a}	87.2^{a}
PCWOPB	20.0^{a}	7.3^{a}	3.5^{b}	3.5^{a}	15^{a}	14.0^{a}	12.0^{a}	13.0^{a}	87.2^{a}
SFCWPB	19.7^{ab}	5.7^{b}	3.2^{b}	4.3^{a}	15^{a}	14.0^{a}	12.0^{a}	12.0^{a}	87.7^{a}
SFCWOPB	19.7^{ab}	5.7^{b}	3.2^{b}	4.3^{a}	15^{a}	14.0^{a}	12.0^{a}	13.0^{a}	87.7^{a}

FCWPB: Forest coffee with pea berry, FCWOPB: Forest coffee without pea berry, GCWPB: Garden coffee with pea berry, GCWOPB: Garden coffee without pea berry, PCWPB: Plantation coffee with pea berry, PCWOPB: Plantation coffee without pea berry, SFCWB: Semi-forest coffee without pea berry, SFCWOPB: Semi-forest coffee without pea berry, **Means followed by the same letter(s) along column showed no significant difference

Table 3: Effect of different production systems on physical and cup quality attributes of coffee beans grown under different production systems in SW Ethiopia

Parameters	Defect	Shape and make	Color	Odor	Cup cleanness	Acidity	Body	Flavor	Overall
Forest	19.0^{b}	8.0^{a}	3.83^{a}	4.6^{a}	15^{a}	13.3^{a}	12.3^{a}	13.3^{a}	87.7^{a}
Garden	19.3^{ab}	7.7^{a}	3.17^{ab}	4.0^{a}	15^{a}	13.3^{a}	11.5^{a}	12.3^{a}	87.2^{a}
Plantation	20.0^{a}	7.7^{a}	3.58^{b}	3.5^{a}	15^{a}	13.8^{a}	12.0^{a}	12.3^{a}	87.2^{a}
Semi-forest	19.7^{b}	5.7^{b}	3.17^{b}	4.25^{a}	15^{a}	14.0^{a}	12.0^{a}	12.0^{a}	87.7^{a}
LSD	0.77	1.18	0.45	ns	ns	ns	ns	ns	ns

ns: Not significant, Means followed by the same letters along the column showed non-significant difference

Table 4: Pearson correlation between bean type and coffee bean quality attributes

Production system and cup traits	Cleanness	Acidity	Body	Flavor	Defect	Shape and make	Color	Odor	Overall
Forest									
Pea berry	-0.25	0.08	0.46	-0.07	0.50	0.39	0.16	0.44	0.11
Normal bean	-0.27	0.59	-0.10	-0.17	-0.69	0.08	-0.04	-0.80	0.43
Garden									
Pea berry	-0.36	0.62	0.04	0.20	-0.33	0.17	0.55	0.55	0.27
Normal bean	-0.48	-0.10	-0.28	0.22	0.26	-0.43	0.03	0.03	-0.04
Semi-forest									
Pea berry	-0.16	0.03	0.66	0.26	0.33	-0.26	0.23	0.18	0.15
Normal bean	-0.11	-0.54	-0.79	0.12	-0.50	-0.59	0.50	0.29	-0.41
Plantation									
Pea berry	-0.38	-0.96**	0.81	-0.48	-0.20	0.53	0.12	0.17	-0.80
Normal bean	0.24	0.93**	-0.68	0.34	0.27	-0.38	-0.26	-0.16	0.70

** Values are significantly correlated

DISCUSSION

The occurrence and distribution of pea berry was significantly influenced by coffee production systems. The highest proportion of pea berry was found in plantation coffee production system. This pattern may be explained by the genotypes of the coffee shrubs. As plantation coffee production systems are planted only with very few improved and preferred cultivars in the form of monoculture, the expected genetic diversity within coffee shrub populations is low. Genetic pools of coffees under the three production systems (forest, semi-forest and garden) might have been similar and this might have been contributed for low occurrence of pea berry. Indeed Wormer (1964) reported that occurrence of pea berry largely depends on the genetic factors. The high proportion of pea berry in plantation coffee production system in this study despite optimum management practices could also be attributed to stiff competition among fruits for available resources. Furthermore, the reduced proportion of pea berry in the forest coffee production system could be attributed to the expected higher diversity of pollinators. Pollination by wild bees increased coffee yields near forest patches and ambient pollination services were adequate in near and intermediate sites. Pollinators also improved coffee quality near forest by reducing the frequency of pea berries (Ricketts *et al*., 2004).

Our results consistently showed absence of significant effect of pea berry on coffee quality. The quality of pea berries was no less than that of the normal beans and some specialist coffee shop sell "Pea berry" alone as a special grade (Ricketts *et al*., 2004). However, since pea berries are smaller in size, they may affect the roasting stage and leads to the lower quality when mixed with normal beans.

The lowest score for shape and make was observed in forest coffee production and difference between the rest of production systems was not significant. Earlier work by Endale (2008) indicated production systems as one of the factors that govern the shape and make quality of coffee beans (rounded, oval, elongated, bourbon, flat and so on). Since all the coffee cherries from all production systems were subjected to the same processing method (wet processing method which contribute to best color and shape and make of coffee bean), the observed variation could be due to the botanical variability or growth environment. Davis *et al*. (2011) also confirmed that the green bean color was best where the mucilage had removed by fermentation under water in wet processing and the poorest color was obtained when the bean dried inside the fruit.

CONCLUSION

The current findings clearly showed significant influence of coffee production system on the occurrence of pea berry. Pea berry occurrence was the highest in plantation production system. The occurrences of the other bean abnormalities observed were found to be very low across all the production systems. We showed that presence of pea berry has no effect on overall quality of coffee bean substantiating earlier report that indicated pea berries are no less than normal beans in quality. Coffee production system had no significant effect on the overall quality. Beans from all coffee production system scored the highest grade point and qualified for the specialty rank suggesting that coffee produced under different production systems in the country remain best quality provided that they are subjected to proper harvesting and postharvest handlings. However, we recommend future study on the causes of bean abnormalities in coffee across coffee production systems as occurrence of pea berry may have yield implication.

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