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Screening of Limu Coffee Selection for Its Quality

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Abstract
Coffee production and supply with excellent quality appear more crucial than ever before for coffee exporting countries. The objective of the study was to screening of Limu coffee landraces selection for acceptable raw and good cup quality for variety development. The study was carried out for three consecutive season starting to 2007/8 to 2009/10 on sixty two Limu landrace accessions and two standard checks. Six kg red ripe coffee cherries collected from each coffee type and prepared under wet processing method at Gera and Agaro. Raw quality (40%); cup quality (60%) and overall quality out of 100 were evaluated. The significant mean difference between treatments mean was compared using LSD at 5% probability level. Highest raw quality value 37.61 at Agaro and 37.50 at Gera were recorded for coffee accession L18/2001and L51/2001respectively. The highest cup quality value 43.11 was recorded for coffee accession L13/2001 at Agaro. At Gera the cup quality was ranging from 46.67 for L16/2001. The significant variations total overall quality in each location was achieved. Coffee accession L16/2001 was showed the highest value (81.67) total quality at Gera; whereas L13/2001 was best for total quality (79.11) at Agaro research site. The considerable variation among accession both for green bean physical and cup quality characteristics shows an opportunity to select coffee accession with desirable quality characteristics. Regardless of productivity and disease resistant character it can be recommended coffee accession having the total quality above 73.00% for the Limu and similar agro ecology.
Keywords: Coffee accession, Cup quality, Limu landrace, Overall quality, Raw quality**.**

INTRODUCTION

Coffee production and supply with excellent quality appear more crucial than ever before for coffee exporting countries. Ethiopia being the center of origin and diversity for arabica coffee, gives a huge comparative advantage and potential to improve coffee yield and quality. This opportunity gives researchers to select of 37 coffee berry diseases (CBD) resistance varieties and acceptable quality coffee for different agro-ecologies of the country. Coffee quality is receiving increasing attention on the international coffee markets, with significant price differentials for high quality and certified coffee. To obtain high yields of good quality coffee, the choice of variety is of fundamental importance. The development of new cultivars has already provided coffee producers high- yielding breeds which are adapted to different cultivation systems and show increased resistance to the major coffee diseases (Wintgens, 2004). Assessment of coffee quality is highly considered as important as productivity and disease resistance in coffee variety development program.

Production and supply of coffee with excellent quality appear more crucial than ever before for coffee exporting countries. Coffee quality refers to beans flavor in fragrance, aroma, flavor, sweetness, acidity or overall taste felt by consumer after drink as well as physical characteristics such as length, width, thickness or weights, shape and color of coffee beans (Giomo et al., 2012**)**. Production of good quality coffee beans in specific areas characterized by their climatic conditions clearly showed that climate is important factor in determining quality of coffee beverage (Silva et al., 2005). The existence of vast genetic variability in *Coffea arabica* accessions of Ethiopia creates the opportunity for improvement through selection with good yield performance, resistance to major diseases with distinct quality characters.

Limu district is one of the major coffee producers of Jimma zone. It is known for its winey flavor. Though its flavor is known in the world market it has no typical variety specific for the locality. To develop variety screening for raw and cup quality from local coffee landrace selection is more important in coffee research. Development of local landraces for each locality largely based on their disease and quality would help to reduce quality adulteration of the inherent quality of known Ethiopian coffee by origin. The objective of the study was to screening of Limu coffee landraces selection for acceptable raw and good cup quality for variety development.

MATERIALS AND METHODS

Description of the study areas

The experiment was conducted at Gera Agricultural Research Sub Center and Agaro trial sites of the Jimma Agricultural Research Center in southwestern Ethiopia. Gera is located at latitudinal gradient of 7º70’’N and longitudinal gradient 36º35’’E with an altitude of 1940 m above sea level. The mean annual rainfall of the area is 1878 mm with an average maximum and minimum air temperatures of 24.4°C and 10.5°C, respectively. Gera is 68 km far from Jimma and 420 km from Addis Ababa. Agaro is located at latitudinal gradient of 7’’50’35 - 7’’ 51’ 00’’ N and longitudinal gradient 36’’35’30’’E with an altitude of 1650 m above sea level. The mean annual

rainfall of the area is 1616 mm with an average maximum and minimum air temperatures of 28.4°C and 12.4°C, respectively. Agaro is 45 km far from Jimma and 397 km from Addis Ababa.

Shading, weeding, fertilizer application and other agronomic practices were uniformly applied to all plots as per the recommendation.

Experimental material

The study was carried out for three consecutive season starting to 2007/8 to 2009/10 on sixty two Limu landrace accessions and two standard checks (744& Dessu at Agaro and 74110 &75227 at Gera). All the agronomic management practices such as shading, weeding and fertilization were uniformly applied to all plots as per the recommendation (Endale et al*.,* 2008).

Sample preparation

Six kg red ripe coffee cherries were handpicked from all replication and bulked for each coffee accession. Over mature, green cherries and foreign material were sorted out from healthy and red ripe cherries before pulping. The samples were carefully prepared using wet processing method at Gera and Agaro. All processing steps pulping, fermentation, washing and drying were done according to (Behailu et al., 2008) based on area altitude. The moisture level of the samples was maintained to 10.5-11.0% for all uniformly during drying.

Raw quality analysis

The dry parchment coffee was hulled and cleaned the green coffee bean. 300g of green bean was used for each sample for raw quality analysis. The percent of retained above screen size 14 (1/64 inch of 14) which means 5.6mm coffee recorded. Raw quality analysis of green bean was used for each sample shape & make (15%), color (15%) and odor (10%) were assessed having 40 % out of the total.

Roasting, grinding and brewing

Hundred gram of green coffee bean for each sample was used for roasting. 200°C heated probatBRZ6 coffee roaster machines was used for to roast in medium level for eight minute (Abrar and et al, 2014). Then cold air was blown through the coffee to produce rapid cooling-off. Using Mahlkoing electrical grinder each sample was grinded to medium size. Soon after grinding, coffee powder weighing about 8g was placed in a cup with a capacity of 180 mL. Then, boiling water was poured on to the ground coffee. The brew was made ready for panelists within 8 min.

Cup quality analysis

It was carried out once the beverage cooled to around 60°C (drinkable temperature). Each sample was prepared in three cups for tasting session. Cup quality attribute aromatic intensity (5%), aromatic quality (5%), bitterness (5%), astringency (5%), acidity (10%), body (10%), flavour (10%) and overall quality (10%) were evaluated out of 60 % by three certified panelists independently for each sample unit of the treatment. Cup quality attributes values were added to analyze the quality out of 60%. Then finally average results of all panelists were used for data analysis.

Overall Total Quality

The total value of raw (40%) and cup quality attributes (60%) was evaluated out of 100% for its overall total quality. It was used for final screening to recommend regardless of yield potential and disease resistant for Limu and similar agro-ecology.

Data analysis

Analysis of variance (ANOVA) was computed for each quality parameter in order to identify the variability among the coffee accession based on the procedures described by Gomez and Gomez (1984). SAS statistical software Version 9.2 (SAS, 2008) was employed for ANOVA, in CRD with three replications. For characters having significant mean differences, the difference between treatment means was compared using LSD at 5% probability level.

RESULTS AND DISCUSSION

Raw Quality

Coffee samples evaluated for above screen 14 (5.60mm) revealed significant variations among coffee accessions for each location and average. At Gera the above screen 14 was ranging from 100 to 89% which full fill the export standard 85% needed. The maximum size 100 % the beans retained above screen 14 accession L06/2001, L07/2001, L21/2001, L53/2001 and L68/2001to the indicated research site. In the case of Agaro the beans retained above screen 14 was ranging from highest value (99 %) of accession L66/2001 to the smaller value 76.59% for accession L38/2001. This indicates the bean size of coffee affected by altitudes. The over location average of coffee bean retention above screen 14 was ranging from highest average value (99.39) to lower value of 86.25%. Accession L21/2001 was showed the maximum above screen 14 percentage of coffee bean retention for three year and two locations average (Table 1).

The average of raw quality showed significant variations among coffee accessions for over two locations and three year average. The raw quality was varying from 37.61 to 30.00; the highest value 37.61 was recorded at Agaro for coffee accession L18/2001 out of 40%. At Gera the raw quality was ranging from 37.50 to

30.22. The highest raw quality (37.50) was achieved for accession L51/2001. The three year over location average raw quality the highest value was 36.83 was observed on accession L06/2001 and accession L16/200 and also the lower raw quality (30.00) result was achieved accession L28/2001. Based on the total raw quality result, variations were detected among coffee accession and also location. Bean physical characteristics such as bean size, shape and make are unified criteria for conducting coffee business within the international market (Agwanda *et al.,* 2003). Detailed summarized result indicated in Table 1.

Table 1: Raw quality coffee accession average of three year and two locations

Ser no.	Acc. No.	% of above screen 14			Raw 40 %		
		Agaro	Gera	Average	Agaro	Gera	Average
1	L01/2001	95.56	97.67	96.61	36.44	35.00	35.72
2	L03/2001	93.44	99.00	96.22	34.78	34.00	34.39
3	L04/2001	97.22	99.00	98.11	34.78	35.50	35.14
4	L06/2001	97.00	100.00	98.50	**36.67**	37.00	**36.83**
5	L07/2001	96.72	100.00	98.36	34.33	37.00	35.67
6	L12/2001	92.79	-	92.79	34.39	-	34.39
7	L13/2001	98.22	98.50	98.36	36.00	31.00	33.50
8	L14/2001	96.61	99.00	97.81	36.22	35.00	35.61
9	L15/2001	97.67	97.50	97.58	**37.00**	34.00	35.50
10	L16/2001	96.33	96.00	96.17	**36.67**	37.00	**36.83**
11	L17/2001	96.44	99.00	97.72	36.44	33.00	34.72
12	L18/2001	96.11	97.00	96.56	**37.61**	34.50	36.06
13	L19/2001	93.33	97.00	95.17	34.78	35.50	35.14
14	L20/2001	95.56	99.00	97.28	34.78	35.50	35.14
15	L21/2001	98.78	100.00	99.39	36.00	34.00	35.00
16	L22/2001	91.00	99.00	95.00	**37.00**	34.50	35.75
17	L23/2001	97.19	98.50	97.84	**37.11**	34.00	35.56
18	L24/2001	91.93	99.00	95.47	35.50	34.00	34.75
19	L25/2001	86.25	-	86.25	36.17	-	36.17
20	L26/2001	94.80	98.33	96.57	35.11	35.00	35.06
21	L27/2001	96.28	99.50	97.89	35.33	35.50	35.42
22	L28/2001	97.50	-	97.50	30.00	-	30.00
23	L29/2001	88.50	-	88.50	33.33	-	33.33
24	L30/2001	96.53	-	96.53	**36.67**	-	**36.67**
25	L32/2001	89.50	96.67	93.08	33.33	36.00	34.67
26	L33/2001	95.22	97.00	96.11	35.00	34.00	34.50
27	L34/2001	95.39	97.00	96.19	35.67	36.00	35.83
28	L35/2001	88.39	94.33	91.36	33.56	35.00	34.28
29	L36/2001	96.73	97.00	96.87	**37.00**	30.22	33.61
30	L37/2001	96.28	99.00	97.64	35.44	36.00	35.72
31	L38/2001	76.59	99.00	87.79	33.78	34.33	34.06
32	L39/2001	86.80	99.00	92.90	35.33	33.33	34.33
33	L40/2001	85.84	98.67	92.26	36.44	35.00	35.72
34	L41/2001	96.02	98.50	97.26	33.33	35.50	34.42
35	L43/2001	87.98	98.39	93.18	34.78	33.56	34.17
36	L44/2001	92.83	98.50	95.67	35.67	34.67	35.17
37	L45/2001	94.50	98.83	96.67	34.00	34.50	34.25
38	L46/2001	94.83	98.00	96.42	30.67	34.00	32.33
39	L47/2001	95.17	97.11	96.14	33.33	33.56	33.44
40	L48/2001	95.33	97.00	96.17	31.00	34.44	32.72
41	L49/2001	80.33	98.17	89.25	33.33	34.50	33.92
42	L50/2001	80.00	98.00	89.00	33.33	34.00	33.67
43	L51/2001	88.67	99.00	93.83	35.67	37.50	**36.58**
44	L52/2001	94.83	89.00	91.92	36.67	34.00	35.33
45	L53/2001	94.83	100.00	97.42	35.33	36.50	35.92
46	L54/2001	97.00	99.00	98.00	35.67	34.00	34.83
47	L55/2001	93.17	99.00	96.08	36.50	35.50	36.00
48	L56/2001	94.33	99.00	96.67	35.00	35.50	35.25

Ser no.	Acc. No.	% of above screen 14			Raw 40 %		
		Agaro	Gera	Average	Agaro	Gera	Average
49	L57/2001	96.00	97.00	96.50	32.00	34.00	33.00
50	L58/2001	92.11	97.00	94.56	34.11	34.00	34.06
51	L59/2001	95.89	98.33	97.11	33.56	34.00	33.78
52	L60/2001	90.00	98.50	94.25	34.67	35.50	35.08
53	L61/2001	96.22	99.33	97.78	34.67	36.00	35.33
54	L62/2001	95.72	98.00	96.86	33.78	34.00	33.89
55	L63/2001	97.56	98.50	98.03	35.44	34.00	34.72
56	L64/2001	90.39	98.00	94.19	34.33	36.00	35.17
57	L65/2001	95.11	98.33	96.72	33.78	37.00	35.39
58	L66/2001	99.00	99.67	99.33	36.00	37.00	**36.50**
59	L67/2001	95.00	99.33	97.17	33.78	36.99	35.39
60	L68/2001	97.56	100.00	98.78	35.11	35.33	35.22
61	L69/2001	98.11	99.33	98.72	35.33	35.01	35.17
62	L70/2001	97.89	99.00	98.44	32.44	36.00	34.22
63	Check 1	97.33	98.00	97.67	35.11	37.00	36.06
64	Check 2	98.22	99.00	98.61	33.56	37.00	35.28
CV%		**4.64**	**0.22**	**2.34**	**2.95**	**2.57**	**2.03**
LSd (5%)		**7.04**	**0.35**	**3.61**	**1.66**	**1.45**	**1.14**

Cup Quality

The cup quality evaluated at Agaro, Gera and average of the two showed significant ($P \leq 0.05$) variations among coffee selections. The average of cup quality showed significant variations among coffee accessions for over two locations and three year average. Cup quality of the accession at Agaro was varying from 43.11 to 31.67. The highest value 43.11 was recorded for coffee accession L13/2001. At Gera the cup quality was ranging from 46.67 to 35.00. Over location and three year average of cup quality highest value was 43.17 was achieved by accession L46/2001 and also the lower cup quality (34.78) was attained by accession L50/2001. The present result showed difference among coffee accession for cup quality attributes. It was reported by Van der Vossen (2005) variation for cup quality character among different *Coffea arabica* L, indicating the presence of great variability among Arabica coffee genotypes. Detailed summarized result indicated in Table 2.

Table 2: Cup quality of coffee accession average of three year and two locations

Ser no.	Acc. No.	Cup quality 60%		
		Agaro	Gera	Average
1	L01/2001	37.11	38.67	37.89
2	L03/2001	40.00	38.33	39.17
3	L04/2001	38.56	42.83	40.69
4	L06/2001	36.56	39.33	37.94
5	L07/2001	37.44	39.67	38.56
6	L12/2001	38.00	-	38.00
7	L13/2001	**43.11**	35.00	39.06
8	L14/2001	34.44	42.94	38.69
9	L15/2001	34.28	42.58	38.43
10	L16/2001	34.78	**44.67**	39.72
11	L17/2001	37.67	41.00	39.33
12	L18/2001	33.56	37.17	35.36
13	L19/2001	33.78	41.67	37.72
14	L20/2001	36.89	43.83	40.36
15	L21/2001	33.56	36.67	35.11
16	L22/2001	32.67	41.17	36.92
17	L23/2001	35.56	41.17	38.36
18	L24/2001	37.50	40.00	38.75
19	L25/2001	37.50	-	37.50
20	L26/2001	37.44	38.28	37.86
21	L27/2001	36.78	**43.83**	40.31
22	L28/2001	36.61	-	36.61
23	L29/2001	38.11	-	38.11
24	L30/2001	40.33	-	40.33

Ser no.	Acc. No.	Cup quality 60%		
		Agaro	Gera	Average
25	L32/2001	37.67	40.78	39.22
26	L33/2001	35.56	37.33	36.44
27	L34/2001	36.22	39.11	37.67
28	L35/2001	37.22	40.56	38.89
29	L36/2001	39.61	35.44	37.53
30	L37/2001	37.89	40.89	39.39
31	L38/2001	37.00	40.78	38.89
32	L39/2001	35.00	40.33	37.67
33	L40/2001	37.56	41.22	39.39
34	L41/2001	37.33	37.67	37.50
35	L43/2001	38.11	**43.83**	40.97
36	L44/2001	38.50	41.33	39.92
37	L45/2001	40.00	41.33	40.67
38	L46/2001	40.33	**46.00**	**43.17**
39	L47/2001	38.67	38.61	38.64
40	L48/2001	36.67	39.40	38.03
41	L49/2001	36.00	36.50	36.25
42	L50/2001	31.67	37.89	34.78
43	L51/2001	38.33	40.50	39.42
44	L52/2001	36.83	41.83	39.33
45	L53/2001	37.00	43.33	40.17
46	L54/2001	35.17	**46.67**	40.92
47	L55/2001	34.67	41.33	38.00
48	L56/2001	35.33	41.00	38.17
49	L57/2001	36.56	40.00	38.28
50	L58/2001	37.56	38.67	38.11
51	L59/2001	36.00	38.67	37.33
52	L60/2001	34.67	38.83	36.75
53	L61/2001	38.00	39.56	38.78
54	L62/2001	37.56	36.67	37.11
55	L63/2001	34.44	40.83	37.64
56	L64/2001	37.67	38.78	38.22
57	L65/2001	37.78	39.78	38.78
58	L66/2001	33.67	40.67	37.17
59	L67/2001	36.44	39.11	37.78
60	L68/2001	**41.78**	**43.11**	42.44
61	L69/2001	36.00	39.44	37.72
62	L70/2001	39.89	39.56	39.72
63	Check 1	35.11	38.89	37.00
64	Check 2	34.89	40.33	37.61
CV%		**9.62**	**6.19**	**6.12**
LSd (5%)		**5.73**	**4.03**	**3.80**

Overall Total Quality

The average of three year results over location showed significant (P≤0.05) variations among coffee selection for overall quality. Coffee selection L68/2001had got better overall and acceptance quality over location. This coffee selection is significantly different and better than the two standard cheeks except (Table 3). The significant variations in each location were achieved. Coffee accession L16/2001 was showed the highest value (81.67) total quality at Gera; whereas L13/2001 was best for total quality (79.11) and acceptable quality at Agaro research site. Coffee selection for the quality traits indicated the existence of variability to screen coffee for variety development for Limu coffee producing areas. The result showed there is presence of large difference among selection for total overall quality attributes. Variation for overall quality character among genotype of Arabica coffee is good opportunity for selection and hybridization. Van der Vossen (2005) also reported mean performance variation for cup quality character among varieties and crosses of *Coffea arabica* L, indicating the presence of great variability among arabica coffee accessions.

Table 3: Total quality of coffee accession average of three year and two locations

Ser no.	Acc. No.	Total quality 100%		
		Agaro	Gera	Average
1	L01/2001	73.56	73.67	73.61
2	L03/2001	74.78	72.33	73.56
3	L04/2001	73.33	78.33	75.83
4	L06/2001	73.22	76.33	74.78
5	L07/2001	71.78	76.67	74.22
6	L12/2001	72.39	-	72.39
7	L13/2001	**79.11**	66.00	72.56
8	L14/2001	70.67	77.94	74.31
9	L15/2001	71.28	76.58	73.93
10	L16/2001	71.44	**81.67**	76.56
11	L17/2001	74.11	74.00	74.06
12	L18/2001	71.17	71.67	71.42
13	L19/2001	68.56	77.17	72.86
14	L20/2001	71.67	79.33	75.50
15	L21/2001	69.56	70.67	70.11
16	L22/2001	69.67	75.67	72.67
17	L23/2001	72.67	75.17	73.92
18	L24/2001	73.00	74.00	73.50
19	L25/2001	73.67	-	73.67
20	L26/2001	72.56	73.28	72.92
21	L27/2001	72.11	79.33	75.72
22	L28/2001	66.61	-	66.61
23	L29/2001	71.44	-	71.44
24	L30/2001	**77.00**	-	77.00
25	L32/2001	71.00	76.78	73.89
26	L33/2001	70.56	71.33	70.94
27	L34/2001	71.89	75.11	73.50
28	L35/2001	70.78	75.56	73.17
29	L36/2001	76.61	65.67	71.14
30	L37/2001	73.33	76.89	75.11
31	L38/2001	70.78	75.11	72.94
32	L39/2001	70.33	73.67	72.00
33	L40/2001	74.00	76.22	75.11
34	L41/2001	70.67	73.17	71.92
35	L43/2001	72.89	77.39	75.14
36	L44/2001	74.17	76.00	75.08
37	L45/2001	74.00	75.83	74.92
38	L46/2001	71.00	80.00	75.50
39	L47/2001	72.00	72.17	72.08
40	L48/2001	67.67	73.84	70.76
41	L49/2001	69.33	71.00	70.17
42	L50/2001	65.00	71.89	68.44
43	L51/2001	74.00	78.00	76.00
44	L52/2001	73.50	75.83	74.67
45	L53/2001	72.33	79.83	76.08
46	L54/2001	70.83	**80.67**	75.75
47	L55/2001	71.17	76.83	74.00
48	L56/2001	70.33	76.50	73.42
49	L57/2001	68.56	74.00	71.28
50	L58/2001	71.67	72.67	72.17
51	L59/2001	69.56	72.67	71.11
52	L60/2001	69.33	74.33	71.83
53	L61/2001	72.67	75.56	74.11

Ser no.	Acc. No.	Total quality 100%		
		Agaro	Gera	Average
54	L62/2001	71.33	70.67	71.00
55	L63/2001	69.89	74.83	72.36
56	L64/2001	72.00	74.78	73.39
57	L65/2001	71.56	76.78	74.17
58	L66/2001	69.67	77.67	73.67
59	L67/2001	70.22	76.10	73.16
60	L68/2001	76.89	78.44	**77.67**
61	L69/2001	71.33	74.46	72.90
62	L70/2001	72.33	75.56	73.94
63	Check 1	70.22	75.89	73.06
64	Check 2	68.44	77.33	72.89
CV%		**5.65**	**3.86**	**3.68**
LSd (5%)		**6.55**	**4.69**	**4.36**

CONCLUSION

The research was conducted for three consecutive years and two locations. From the result by considering the overall total coffee quality is used to determine and evaluate the quality potential of the coffee accession. Considerable variation was observed among accession both for green bean physical and cup quality characteristics. Therefore there is an opportunity to select coffee accession with desirable coffee quality characteristics. Regardless of disease resistant and productivity character it can be recommended coffee accession having the total quality above 73.00% for the Limu and similar agro ecology.

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REFERENCES

Abrar Sualeh, Solomon Endris and Ali Mohammed, 2014. Processing Method, Variety and Roasting Effect on Cup Quality of Arabica Coffee (*Coffea arabica* L.); Discourse Journal of Agriculture and Food Sciences, 2(2): 70-75.

Agwanda, C O, Baradat P, Eskes A B, Cilas C and Charrier A, (2003). Selection for bean and liquor qualities within related hybrids of arabica coffee in multi-local field trials. Euphytica 131: 1-14.

Behailu Weldsenbet, Abrar Sualeh, Nugussie Mekonen, Solomon Endries, (2008). Coffee processing and quality research in Ethiopia. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia. Pp: 307-316.

Endale T, Taye K, Antenhe N, Tesfaye S, Alemseged Y, Tesfaye A (2008). Research on coffee field management. pp.187-195. In: Girma A, Bayetta B, Tesfaye,S, Endale T, Taye K (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

Gomez KA and Gomez AA (1984). Statistical procedure for Agricultural Research (2nd) John Wiley and Sons, New York.

SAS (Statistical Analysis System) (2008). (Version 9.2). SAS Institute, Cary, NC. USA.

Silva EA, Mazzafera P, Brunini O, Sakai E, Arruda FB, Mattoso LHC, Carvalho C RL and Pires RCM (2005). The influence of water management and environmental conditions of the chemical composition and beverage quality of coffee beans. Brazilian Journal of Plant Physiology; 17 (2): 229-238.

Van der Vossen HAM (2005). Diversity of arabica coffee genotypes. In: M.N. Clifford and K.C. Wilson (eds.), Coffee Botany, Biochemistry and Production of Beans and Beverages. Croom Helm, London and New York, pp. 49-96.

Wintegens, J.N.2004.Coffee: Growing, processing, sustainable production, a guide book for growers, processors, traders, and researchers, Wiley-VCH Verlag GmbH &Co.KGaA, Weinheium.