Research Article

Physical and Cup Quality Attributes of Arabica Coffee (*Coffea arabica* L.) Varieties Grown in Highlands of Amhara Region, Northwestern Ethiopia

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Coffee is the second most traded commodity worldwide after oil both in terms of volume and value. The study was therefore initiated to evaluate the quality of highland coffee varieties grown in the region. For this purpose, coffee bean samples of the varieties Merdacheriko, Yachi, Wush Wush, Buno wash, 741, 7440, Ababuna, and Ageze were collected from trees which were grown in Adet and Woramit Agricultural Research Centers in RCBD with three replications. Physical (length and width of coffee beans, 100 bean weight, screen sizes, and raw quality) and cup quality (aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor, overall standard, and total cup quality) parameters, as well as total coffee quality, were evaluated by a team of certified panelists at Jimma Agricultural Research Center. The results depicted significant variations in physical quality parameters of coffee varieties, while the cup and total qualities of coffee varieties in WARC and in AARC were similar. In WARC, Buno wash, Wush Wush, and Ababuna coffee varieties showed better physical quality in terms of 100 bean weight, bean length, bean width, and screen size, while varieties Buno wash and Wush Wush showed better physical quality only in terms of 100 bean weight and bean length in AARC. Cup quality of coffee varieties grown in WARC ranged from 48.16% to 51.33% while that of coffees grown in AARC ranged from 45.00% to 50.83%. Total coffee quality in WARC was at the range from 85.50 to 89.33% while in AARC from 81.66 to 87.83%, which is within the standard of Ethiopian Commodity Exchange for coffee. All the tested varieties of Arabica coffee can be therefore used to produce coffee in both study areas and areas with similar agroecology of the Amhara Region, Ethiopia. Further research on the yield performance of the coffee varieties is also recommended.

1. Introduction

Coffee is the second most traded commodity worldwide after oil both in terms of volume and value [1]. The crop is grown in the tropical and subtropical climates of the world where over 10.2 million hectares of land in more than 80 countries are covered by the crop. Coffee is a significant source of income for several developing countries in Africa, Asia, and Latin America [2], including Ethiopia. Brazil is the leading coffee producing country followed by Vietnam, Colombia, and Indonesia. According to ICO [3], Ethiopia contributed about 4.2% of the total world coffee production. The production of coffee in Ethiopia is showing an increasing trend where the current production is estimated to be 449,229.8 t on 725,961.2 hectares of land with an average productivity of 0.612 t ha$^{-1}$ clean coffee as indicated by Central Statistical Agency (CSA) [4]. In the Amhara region, the production of coffee is estimated to be 3,006.8 t with the productivity of 0.302 t ha$^{-1}$ [4].

Ethiopia is the center of origin for Arabica coffee (*Coffea arabica* L.), which is mild and has excellent liquor
quality and preferred in the world market [5]. Coffee quality is of critical importance to the coffee industry where the quality encompasses fragrance, aroma, flavor, sweetness, and acidity and physical characteristics such as length, width, thickness or weights, shape, and color of coffee beans [6, 7]. On the other hand, coffee quality is strongly influenced by environmental factors including altitude, daily temperature fluctuations, amount and distribution of rainfall, and physical and chemical properties of the soils [8]. Accordingly, the production of good quality coffee beans in specific areas is influenced by the climatic and edaphic conditions of the production areas as indicated by Silva et al. [9]. Moreover, coffee quality also depends on the genetic makeup of the genotype/variety of coffee. According to Yigzaw [10] and Leroy et al. [11], genetic origins greatly influenced coffee quality as it favors genes of chemical compounds that behave as aroma precursors expressed during the coffee roasting process.

Although Ethiopia is the center of origin for Arabica coffee, the country’s coffee industry is generally characterized by low quality and productivity including the Amhara Region. The main objective of the present study was therefore to analyze cup and physical quality of Arabica coffee varieties grown in highlands of the Amhara Region.

2. Materials and Methods

2.1. Description of the Study Areas. The study was conducted on coffee varieties which were grown at Adet Agricultural Research Center (AARC) and Woramit Agricultural Research Center (WARC). AARC is located at 11°17’N latitude and 37°43’E longitude (Figure 1) with an altitude of 2240 masl. It receives a unimodal rainfall pattern, which extends from early June to late September where June, July, and August are the three important months with the high and more or less uniform spatial distribution. The mean annual average rainfall of the experimental site is about 1432 mm, while the annual average minimum and maximum temperatures are 10.81°C and 25.55°C, respectively (Bahir Dar Metrology Agency, 2018).

The soil of AARC is nitosol with a textural classification of clay and a pH of 5.17. It has very low organic matter content (1.898%). The available phosphorus and total nitrogen contents of the soil are 1.688 mg/kg and 0.0949%, respectively. Cation exchange capacity and K+ content of the soil are 25.32 cmol/kg and 0.45 cm/kg, respectively.

WARC is found in the northwestern part of Bahir Dar city on the shore of Lake Tana, which is located at 11°38’N latitude and 37°10’E longitude (Figure 1). The altitude of WARC is 1800m above sea level with a warm and humid climate and distinct dry and wet seasons. It receives the mean annual rainfall between 800 and 1250 mm (Bahir Dar Metrology Agency, 2018) with annual average maximum and minimum temperatures of 30°C and 13°C, respectively. Generally, the area is characterized as midaltitude agroecology.

The soil of WARC is nitosol with moderately acidic pH 6.4 and has the textural classification of clay with very low organic matter content (3.9%). The available phosphorus content of the soil is low (6.3 mg/kg) while the total nitrogen content is 0.16% medium [12].

2.2. Coffee Varieties Used for the Study. Coffee beans of eight Arabica coffee varieties that were planted at Adet and
Woramit Agricultural Research Centers for adaptation trail were used in the present study. The seven varieties (Merdacheriko, Yachi, Wush Wush, Buno wash, 741, Ababuna, and 7440) were brought from Jimma Agricultural Research Center, while Ageze variety was used as a local check (Table 1). The coffee trees are grown under the Sesbania sesban tree as temporal shade.

2.3. Experimental Procedures and Data Collection

2.3.1. Harvesting and Sample Preparation of Coffee Cherries. For physical and cup quality analysis, well-ripened coffee cherries of each variety were hand-harvested and dried on a raised bed, which was constructed using local materials and mesh wire. Two harvests were made to have the required amount of beans, which were necessary for the study. Each harvest was dried separately where the harvested red cherries during each harvest were weighted. The dried cherries from each butch of harvest were mixed thoroughly, and a sample of 400g clean beans of each variety was collected and taken to Jimma Agricultural Research Center for physical and cup quality analysis.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Origin/zone</th>
<th>Year of release</th>
<th>Quality Analysis</th>
<th>Similar Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merdacheriko</td>
<td>Gera/Jimma</td>
<td>2006</td>
<td>Research field</td>
<td>Farmers field</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Altitude (m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1750–2100</td>
<td>⩾1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Temperature (°C)</td>
<td>10–26</td>
</tr>
<tr>
<td>Yachi</td>
<td>Yachi/Jimma</td>
<td>2006</td>
<td>1.9</td>
<td>1.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1750–2100</td>
<td>⩾1500</td>
</tr>
<tr>
<td>Wush Wush</td>
<td>Wush Wush/Kaffa</td>
<td>2006</td>
<td>2.35</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1750–2100</td>
<td>⩾1500</td>
</tr>
<tr>
<td>Buno wash</td>
<td>Wush/Kaffa</td>
<td>2006</td>
<td>1.22</td>
<td>1.56</td>
</tr>
<tr>
<td>741</td>
<td>Gera/Jimma</td>
<td>1977/78</td>
<td>1.62</td>
<td>0.6–0.7</td>
</tr>
<tr>
<td>7440</td>
<td>Wushi/Kaffa</td>
<td>1979/80</td>
<td>2.38</td>
<td>0.8–0.9</td>
</tr>
<tr>
<td>Ababuna</td>
<td>Hybrid coffee</td>
<td>1978/79</td>
<td>2.38</td>
<td>1.5–1.6</td>
</tr>
<tr>
<td>(741xDessu)</td>
<td></td>
<td></td>
<td>1000–1752</td>
<td>⩾1400</td>
</tr>
<tr>
<td>Ageze</td>
<td>Local</td>
<td></td>
<td></td>
<td>15–30</td>
</tr>
</tbody>
</table>

Source: Demelash and Kifle [13].

2.3.2. Evaluation of Physical Quality Parameters of Coffee. The collected samples were assigned identification code randomly to avoid unbiased judgment and sun-dried up to moisture contents between 10.5% and 11.5%. The raw quality parameters of the coffee samples were evaluated following the standard procedures as described by Abrar and Negussie [14].

(1) Bean Sizes (mm). First, about 30 clean green beans samples were randomly selected from each sample using a rotary sample divider (Laborette 27 FRITSCH, Germany). The length (L) and width (W) of the sample beans were then measured along the major axis and minor axis, respectively, using an electronic digital vernier caliper with 0.01 mm accuracy.

(2) 100 Seed Weight (g). The weights of 100 green coffee seeds randomly selected from each sample were weighed using sensitive balance, and mean values were computed and used for analysis.

(3) Screen Size (%). Bean size distribution was analyzed using a perforated screen plate where a 14/64 inch diameter screen was used. The coffee beans above the screen size 14 were weighed and recorded as a percentage.

(4) Raw Quality (%). This coffee quality attribute was evaluated by experienced coffee testers in the percentage of 40%, which is the summation of the average values of shape and makes (15%), color (15%), and odor (10%) as indicated by Abrar and Negussie [14]. Shape and make as boldness and uniformity of the sample bean was evaluated subjectively as very good = 15, good = 12, fairly good = 10, average = 8, mixed = 6, and small = 4. The weight of each category was expressed in percentage and used for analysis. The color of sample coffee beans was evaluated subjectively as bluish = 5, grayish = 4, greenish = 3, coated = 2, faded = 1, and white = 0. Each category was weighed separately and expressed as percentage. Similarly, odor of the sample green coffee beans was evaluated subjectively as clean = 10, fair clean = 8, trace = 6, light = 4, moderate = 2, and strong = 0. Each category was then weighed separately and expressed as percentage.

2.3.3. Evaluation of Cup Quality Parameters of Coffee

(1) Cup Preparation Methods. To evaluate the cup quality, 100 g green coffee beans of each sample was put into the roasting cylinder after heating the roaster machine up to the temperature between 180°C and 200°C. The sample beans were roasted for six minutes to roast them to medium color [14] where beans above the screen size 14 were used for roasting. Half of the roasted coffee samples were ground to medium size using an electric grinder, and grounded samples were kept in a plastic bag. After grinding of each sample, the grinder was cleaned thoroughly to avoid the mix up of one sample from another.

For the preparation of brew, eight grams of powdered coffee sample was used to each cup, which has 180 ml capacity, where 3 cups per sample unit were prepared. Freshly boiled water was poured to fill about half of the cup, which contained the grounded sample coffee and stirred to ensure the homogeneity of the mixture [15]. The volatile aromatic quality and its intensity were evaluated by sniffing of the
cuppers before filling the cups with hot water. After evaluation, the cups were filled to full size (180 ml) and left undisturbed for three minutes for the settling of the grinds, and then, the floaters were skimmed, and the brew was ready for cup quality testing.

Cup qualities were tested by three experienced and certified professional panelists (cuppers) as described by Abrar and Negussie [14]. Each panelist gave his/her independent judgment using cupping form where finally the average means of the records of the panelists were used.

(2) Evaluation of Cup Quality Parameters. Cup quality parameters including cup cleanness, acidity, body, and flavor were evaluated by cuppers following the standard procedures described by Abrar and Negussie [14].

Aromatic intensity (%): it is a magnitude of aroma of the beverage which was evaluated using the scale 0–5, where 0 = nil, 1 = very light, 2 = light, 3 = medium, 4 = strong, and 5 = very strong and weighted at 5%.

Aromatic quality (%): it is evaluated by a sense of the cuppers, which is relatively hard to separate from the flavor. The aromatic quality was evaluated using the scale 0–5, where 0 = nil, 1 = bad, 2 = regular, 3 = good, 4 = very good, and 5 = excellent and weighted at 5%.

Acidity (%): it is a sense of dryness of the coffee brew. It was evaluated using the scales ranging from 0 to 10, where 0 = nil, 2 = very light, 4 = light, 6 = medium, 8 = strong, and 10 = very strong and weighted at 10%.

Astringency (%): it describes the complex sensation accompanied by shrinking, drawing, or puckering of the coffee in the mouth of the cuppers produced by tannins. It was evaluated using a scale ranging from 0 to 5, where 5 = nil, 4 = very light, 3 = light, 2 = medium, 1 = strong, and 0 = very strong and weighted at 5%.

Body (%): body is a feeling of coffee in our mouth. It is the viscosity, heaviness, thickness, or richness that is perceived on the tongue. It was evaluated using a scale ranging from 0 to 10, where 0 = nil, 2 = very light, 4 = light, 6 = medium, 8 = strong, and 10 = very strong and weighted at 10%.

Bitterness (%): bitterness is the perception of coffee testers towards the coffee brew on their tongue during cup tasting. It is opposite to sweetness which was evaluated using a scale ranging from 0 to 5, where 5 = nil, 4 = very light, 3 = light, 2 = medium, 1 = strong, and 0 = very strong and weighted at 5%.

Flavor (%): it is the overall perception of the panelists towards the acidity, aroma, and body of the brew. It balances these quality attributes which was scaled from 0 to 10, where 0 = unacceptable, 2 = bad, 4 = fire, 6 = average, 8 = good, and 10 = very good and weighted at 10%.

Overall standard: it can be recorded based on all the liquor quality attributes (intensity, aromatic quality, acidity, astringency, body, bitterness, and flavor). The scale was ranges from 0 to 10, where 0 = unacceptable, 2 = bad, 4 = regular, 6 = good, 8 = very good, and 10 = excellent.

Cup quality (%): it is the summation of aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor, and overall standard, which was evaluated in 60%.

Overall coffee quality: it was determined by the summation of raw and cup quality parameters of the coffee, which were weighted out of 40% and 60%, respectively.

2.4. Data Analysis. The collected data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) of the Statistical Software Program, SAS, version 9.4 [16]. Whenever ANOVA showed significant variation, the mean separation was conducted using least significant difference (LSD) at 5%, 1%, and 0.1% probability level depending on the ANOVA results.

3. Results and Discussion

3.1. Physical Quality Parameters of Arabica Coffee Varieties Grown in WARC and AARC

3.1.1. Bean Length. The analysis of variance revealed that coffee bean length was significantly influenced \( P \leq 0.05 \) by the variety in both experimental locations. At Woramit Agricultural Research Center, the highest coffee bean lengths were recorded from Wush Wush (10.6 mm), Buno wash (10.52 mm), Merdacheriko (10.13 mm), and Ageze (10.19 mm) coffee varieties, which were statistically similar when compared each other. The smallest bean lengths were recorded from Yachi (9.63 mm), 741 (9.81 mm), 7440 (9.81 mm), and Ababuna (9.82 mm) varieties, which were similar statistically (Table 2). Similarly, at Adet Research Center, Wush Wush (10.42 mm) and Buno wash (10.34 mm) coffee varieties recorded the highest bean length, while 741, Yachi, and Ababuna varieties recorded the smallest bean length (Table 3).

As indicated in the present study, bean length was influenced by environmental conditions and coffee varieties used. Based on the results, bean lengths of coffee varieties grown at AARC were relatively longer than those grown in WARC, which could be associated with the environmental conditions of the research sites. Similarly, coffee bean lengths varied with varieties, which may associate with the genetic makeup of the varieties. In agreement with these results, other researchers also reported differences in physical parameters of coffee beans among Arabica coffee varieties, which could be associated with the genetic makeup [17, 18].

3.1.2. Bean Width. The analysis of variance revealed a significant variation \( P \leq 0.05 \) on coffee bean width among coffee varieties grown at WARC. However, this parameter was not influenced by varieties at AARC. The highest bean widths at Woramit Agricultural Research Center were obtained from Buno wash (7.13 mm), Ababuna, and Ageze coffee varieties, which were statistically similar when
compared to each other. On the other hand, the smallest 100 seed weights ranging from 12.56 to 12.70 g (Table 3). While the other varieties recorded the smallest 100 seed weights ranging from 13.36 g to 15.80 g, while the other varieties recorded the smallest and Merdacheriko (16.86 g) coffee varieties, which were similar in weight, while the other varieties recorded the smallest and statistically similar 100 seed weights ranging from 14.60 g (Yachi) to 15.86 g (Ababuna). At AARC, Buno wash, Ageze, 7440, Wush Wush, and Merdacheriko varieties recorded the highest 100 seed weights ranging from 13.36 g to 15.80 g, while the other varieties recorded the smallest 100 seed weights ranging from 12.56 to 12.70 g (Table 3).

### Table 2: Physical quality parameters of beans of Arabica coffee varieties grown in WARC during the 2018 main cropping season.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Scr (%)</th>
<th>100 SW (g)</th>
<th>BL (mm)</th>
<th>BW (mm)</th>
<th>SM (15%)</th>
<th>CL (15%)</th>
<th>OD (10%)</th>
<th>RQ (40%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ababuna</td>
<td>92.33</td>
<td>12.66</td>
<td>9.30</td>
<td>6.06</td>
<td>12.66</td>
<td>13.33</td>
<td>9.66</td>
<td>36.43</td>
</tr>
<tr>
<td>7440</td>
<td>93.66</td>
<td>13.83</td>
<td>9.45</td>
<td>5.51</td>
<td>13.83</td>
<td>13.83</td>
<td>9.66</td>
<td>36.66</td>
</tr>
<tr>
<td>Ababuna</td>
<td>98.00</td>
<td>15.86</td>
<td>9.82</td>
<td>6.89</td>
<td>14.00</td>
<td>14.00</td>
<td>9.66</td>
<td>38.00</td>
</tr>
<tr>
<td>Ageze</td>
<td>97.33</td>
<td>17.20</td>
<td>10.19</td>
<td>6.67</td>
<td>13.83</td>
<td>13.83</td>
<td>9.66</td>
<td>37.66</td>
</tr>
<tr>
<td>CV</td>
<td>1.02</td>
<td>5.01</td>
<td>4.30</td>
<td>4.20</td>
<td>3.06</td>
<td>3.06</td>
<td>3.09</td>
<td>1.79</td>
</tr>
<tr>
<td>P values</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>SE±</td>
<td>0.20</td>
<td>0.73</td>
<td>0.11</td>
<td>0.20</td>
<td>0.07</td>
<td>0.13</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

Note. Means in column followed with the same letter/s are not significantly different; Scr = screen size above 14; 100 SW = hundred seed weight; BL = bean length; BW = bean width; BT = bean thickness; CV = coefficient of variance; LSD = least significance difference; *significant at (P ≤ 0.05); **highly significantly different at P ≤ 0.01; SE = standard error; SM = shape and make; CL = color; OD = odor; RQ = total raw quality.

### Table 3: Physical quality parameters of beans of Arabica coffee varieties grown in AARC during the 2018 main cropping season.

<table>
<thead>
<tr>
<th>Coffee varieties</th>
<th>Scr (%)</th>
<th>100 BW (g)</th>
<th>BL (mm)</th>
<th>BW (mm)</th>
<th>SM (15%)</th>
<th>CL (15%)</th>
<th>OD (10%)</th>
<th>RQ (40%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ababuna</td>
<td>90.66</td>
<td>13.36</td>
<td>9.84</td>
<td>6.25</td>
<td>12.66</td>
<td>13.66</td>
<td>9.66</td>
<td>36.00</td>
</tr>
<tr>
<td>741</td>
<td>91.00</td>
<td>13.58</td>
<td>9.60</td>
<td>6.06</td>
<td>12.66</td>
<td>13.66</td>
<td>9.66</td>
<td>36.00</td>
</tr>
<tr>
<td>Buno wash</td>
<td>92.66</td>
<td>13.76</td>
<td>10.42</td>
<td>5.90</td>
<td>14.00</td>
<td>14.00</td>
<td>9.33</td>
<td>37.33</td>
</tr>
<tr>
<td>Wush Wush</td>
<td>92.00</td>
<td>15.80</td>
<td>10.34</td>
<td>6.86</td>
<td>13.33</td>
<td>13.33</td>
<td>9.33</td>
<td>36.33</td>
</tr>
<tr>
<td>Ababuna</td>
<td>92.33</td>
<td>12.66</td>
<td>9.30</td>
<td>6.06</td>
<td>12.66</td>
<td>13.33</td>
<td>9.66</td>
<td>36.66</td>
</tr>
<tr>
<td>Ageze</td>
<td>90.33</td>
<td>13.96</td>
<td>9.45</td>
<td>6.27</td>
<td>13.50</td>
<td>13.33</td>
<td>9.66</td>
<td>36.50</td>
</tr>
<tr>
<td>Mean</td>
<td>91.70</td>
<td>13.58</td>
<td>9.60</td>
<td>6.06</td>
<td>13.33</td>
<td>13.33</td>
<td>9.45</td>
<td>36.43</td>
</tr>
<tr>
<td>CV</td>
<td>3.31</td>
<td>11.26</td>
<td>5.46</td>
<td>8.85</td>
<td>5.73</td>
<td>4.61</td>
<td>4.31</td>
<td>3.57</td>
</tr>
<tr>
<td>P values</td>
<td>*</td>
<td>*</td>
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<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (P ≤ 0.05)</td>
<td>2.67</td>
<td>0.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE±</td>
<td>0.53</td>
<td>0.32</td>
<td>0.13</td>
<td>0.11</td>
<td>0.18</td>
<td>0.12</td>
<td>0.12</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Note. Means in column followed with the same letter/s are not significantly different; ns = no significant difference; Scr = screen size above 14; 100 BW = hundred bean weight; BL = bean length; BW = bean width; BT = bean thickness; CV = coefficient of variance; LSD = least significance difference; *significant at (P ≤ 0.05); SE = standard error; SM = shape and make; CL = color; OD = odor; RQ = total raw quality.

Coffee beans grown in WARC were relatively wider in width than those grown in AARC, which can be due to the differences in environmental conditions and the physical and chemical characteristics of the soil of the sites. Bigger widths of coffee beans grown in WARC is obviously associated with higher temperatures in lower altitude, which improve the vegetative growth through enhanced photosynthetic activities, which in turn improved assimilate accumulation in beans for a wider width. In Adet, on the other hand, the temperature is relatively low, which generally reduces the growth rate and development of plants including bean width. Moreover, the content of phosphorous and nitrogen in the soil of WARC was relatively higher than that of AARC, which may enhance the width of coffee beans that in turn may lead to differences in bean width among coffee varieties in WARC than in AARC. The results of the present study are in agreement with the findings of other researchers where environmental conditions and soil properties influenced the size of coffee beans [8, 19]. Similar to the present study, Dessalegn et al. [20] and Muschler [21] observed variations of coffee bean size, which is influenced by environmental conditions and soil fertility.

#### 3.1.3. Hundred Seed Weight

Varieties grown in WARC had a very significant effect (P ≤ 0.01) on hundred seed weight, while a significant varietal difference on hundred seed weight (P ≤ 0.05) was observed in coffee varieties grown in AARC. At WARC, the highest 100 seed weights were recorded from Buno wash (17.93 g), Ageze (17.20 g), and Merdacheriko (16.86 g) coffee varieties, which were similar in weight, while the other varieties recorded the smallest and statistically similar 100 seed weights ranging from 14.60 g (Yachi) to 15.86 g (Ababuna). At AARC, Buno wash, Ageze, 7440, Wush Wush, and Merdacheriko varieties recorded the highest 100 seed weights ranging from 13.36 g to 15.80 g, while the other varieties recorded the smallest 100 seed weights ranging from 12.56 to 12.70 g (Table 3).
Greater hundred seed weight of coffee beans collected from coffee trees grown in WARC could be associated with the environment and edaphic conditions of the site. WARC has a relatively warmer temperature and high sunlight, which may hasten photosynthetic processes, and thus the accumulation of more assimilates that in turn resulting bigger coffee bean. Moreover, the fertility of the soil of WARC in terms of nitrogen and phosphorous was much better than the soil of AARC as indicated above, which may have its contribution on the production of bigger coffee beans. Furthermore, WARC is located at midaltitude, which is generally best suited to Arabica coffee than AARC, where it is located at relatively high altitude as indicated above. In this regard, Zuillo et al. [22] and Magrach and Ghazoul [23] also reported that coffee growing areas that are located at midaltitude are especially suitable for growth, development, and production of Arabica coffee.

3.1.4. Screen Size. The analysis of variance revealed significant variation \((P \leq 0.05)\) on screen size among varieties grown at WARC. However, screen size was not influenced by varieties at AARC. Except for the variety 7440 (96.0%), all other varieties grown at WARC recorded the highest percentages screen size above 14 that ranged from 96.66% to 98.0% (Table 2), which could be associated with suitable environmental and edaphic conditions such as high temperature, plenty of sunshine, and relatively better phosphorous and nitrogen contents in the soil. The screen sizes of coffee beans grown in AARC were relatively low, statistically similar, and ranged from 90.33 to 93.66% (Table 3), which were relatively low and statistically similar. The reasons for this scenario may be relatively high altitude, low temperature, and scarce sunshine in areas with relatively high altitude that in turn affect the overall performance of coffee plants.

As indicated in Table 3, the percentages of the screen size above 14 of the coffee varieties grown at WARC were generally greater than those grown at AARC, which could be due to warmthness and availability of more sunlight at relatively midaltitude areas such as WARC. More phosphorous and nitrogen that were found in the soil of WARC may also contribute to variation in screen size and bigger coffee bean sizes of varieties grown in WARC. According to ECX [24], more than 85% of the coffee beans should be retained by the screen size of 14 to fulfill the Ethiopian Coffee Grading System. Accordingly, all the tested varieties grown in both experimental sites fulfilled the Ethiopian coffee standard.

3.1.5. Raw Quality. The analysis of variance revealed that beans of coffee varieties grown in WARC and AARC were statistically similar in shape and make, color, and odor. Shape and make, color, and odor of all varieties grown in WARC were ranged from 13.83% to 14.16%, 13.50% to 14.16%, and 9.33% to 9.66%, respectively (Table 2), while the shape and make, color, and odor of those grown in AARC were from 12.66% to 14.00%, 13.58% to 14.08%, and 9.00% to 9.66%, respectively (Table 3). Similarly, total raw quality as the summation of shape and make, color, and odor were also not influenced by coffee varieties that were grown in WARC and AARC. The total raw qualities of all varieties grown in WARC were ranged from 37.00% to 38.00% (Table 2), while those grown in AARC were 36.00% to 37.33% (Table 3).

The results of the present study indicated that the raw qualities (shape and make, color, and odor) of Arabica coffee varieties, which were similar across the study area, are probably influenced more by the genetic makeup of the varieties rather than the environmental conditions of the growing areas [11].

3.2. Cup Quality Parameters of Arabica Coffee Varieties Grown in WARC and AARC

3.2.1. Aromatic Intensity and Quality. The analysis of variance showed that aromatic intensity and quality were not statistically influenced by the coffee varieties grown in both locations. The aromatic intensities of coffee varieties grown in WARC and AARC were ranged from 4.00% to 4.5% and 4.00% to 4.33%, respectively (Tables 4 and 5). Similarly, aromatic qualities of coffee varieties grown in WARC were between 3.66% and 4.33% while those grown in AARC between 3.83% and 4.16% (Tables 4 and 5). According to Abrar and Nigussei [14], the aromatic intensity of Arabica coffee varieties grown in both locations was rated between strong and very strong while the aromatic quality was between good and very good. The results of the present study indicated that all varieties grown in both locations are good both in their aromatic intensity and quality and thus suitable for being produced in the study area.

Aromatic intensity and aromatic quality are the most important cup quality parameters, which determine the magnitude of the aroma of the coffee beverage and influence the sense organ of the cuppers [14]. While aromatic intensity is influenced by aromatic compounds in the coffee beans, aromatic quality is affected by the profile of volatile compounds [25, 26]. Both of them could be influenced by environmental conditions, soil types, and coffee varieties [25, 27–29]. In this regard, Arabica coffee is better in aromatic intensity than Robusta coffee and thus has a very good quality [26, 30].

3.2.2. Acidity and Astringency. The analysis of variance revealed that acidity and astringency of coffee beans were not statistically influenced by coffee varieties in both locations. The acidity of coffee varieties grown in WARC and AARC was ranged from 8.16% to 8.66% and 7.66% to 8.50%, respectively (Tables 4 and 5). Similarly, the astringency of coffee varieties grown in WARC and AARC was between 3.83% and 4.16% (Tables 4 and 5). The results showed that all varieties grown in both locations have similar and relatively lower acidity and astringency content, which are probably more influenced by coffee varieties rather than the environmental conditions. This in turn implies the suitability of all the tested coffee varieties in terms of cup quality for being produced in the study areas.
The acidity of coffee beans is a sense of dryness of the coffee brew, while astringency describes the complex sensation of the coffee in the mouth of the cuppers, which is produced by tannins found in the coffee beans [14]. According to the authors, the acidity of beans collected from coffee varieties grown in both locations is scaled as a medium level. Similarly, the astringency of beans of coffee varieties from both locations is scaled between very light and nil, which indicates a relatively low quantity of astringency and thus good in quality. Coffee beans with low content of astringency have generally high quality [21, 31, 32]. In general, Robusta coffee is known for a bitter taste and astringency, while Arabica develops a fine acidity, better flavor, and is more intense in overall aroma [33, 34].

3.2.3. Bitterness and Body. The analysis of variance revealed that bitterness and body of beans were not influenced by the variety in both locations. The bitterness level of the coffee varieties grown in both locations is scaled between very light and nil, while the body of the beans is categorized as medium-full as indicated by Abrar and Negussie [14]. Bitterness and body are also the other important cup quality parameters of coffee, which generally influence the cup and coffee qualities. Good coffee quality generally should have relatively low bitterness and medium to full body, which is fulfilled by almost all Arabica coffee varieties tested [14]. The results also imply the suitability of all the tested Arabica coffee varieties in terms of bitterness and body for coffee production in the study areas. In this regard, it is also important to note that the perceived bitterness of coffee depends on the temperatures of the coffee brew where coffee brewed at cooler water is bitter than coffee brewed at hot water. These phenomena are associated with the release of heightened aromatics in hot brewed coffee, which counteract the bitterness of the coffee [35].

3.2.4. The Flavor and Overall Standard. The statistical analysis of flavor and overall standard of coffee beans...
showed no significant variation among coffee varieties at both locations. The flavor of coffee varieties grown in WARC and AARC was ranged from 7.66% to 8.16% and 7.50% to 8.50%, respectively (Tables 4 and 5). Similarly, the overall standard of coffee varieties grown in WARC and AARC was ranged from 7.83% to 8.66% and 7.66% to 8.33%, respectively (Tables 4 and 5). The flavor of the coffee varieties grown in both locations is scaled between average and very good, while the overall standard of the beans is scaled between good and excellent as indicated by Abrar and Negussie [14].

Flavor and overall standard of the tested coffee varieties grown in WARC and AARC are similar and at acceptable range based on the quality standard set by Ethiopian Commodity Exchange [24]. The results also indicate suitability of the tested Arabica coffee varieties for coffee production in the study area in terms of flavor and overall standard. In agreement of this finding, Baggenstoss et al. [36] reported that the coffee’s species, variety, geographic origin, and level of roasting determine the constitution and quantity of the flavor.

3.2.5. Cup and Overall Coffee Qualities. Cup quality of coffee beans was computed by the summation of aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor, and overall standard, which is evaluated from 60%. On the other hand, overall coffee quality was evaluated from 100%, which is a summation of raw (40%), and cup (60%) quality. The statistical analysis of cup and coffee qualities showed no significant variations in total cup and coffee qualities of coffee varieties grown in both locations. The total cup quality of coffee varieties ranged from 48.16% (Yachi variety) to 51.33% (7440 variety) in WARC and from 45.00% (7440 variety) to 50.83% (Yachi variety) in AARC. On the other hand, the total coffee quality ranged from 85.50% (Yachi variety) to 89.33% (7440 variety) in WARC and from 81.66% (7440 variety) to 87.83% (Yachi variety) in AARC (Tables 4 and 5). Therefore, in both locations, the total coffee quality ranged from 81.66% to 89.33%, which has grade 2 values [24].

Cup and overall coffee quality of the tested Arabica coffee varieties was statistically similar and satisfy the quality standard set by Ethiopian Commodity Exchange [24]. All the tested Arabica coffee varieties are therefore suitable in terms of quality for being produced in the study areas, although there are differences in altitude, environmental, weather, and edaphic conditions [37].

4. Conclusion and Recommendation

The results of the present study showed that most physical quality parameters of Arabica coffee varieties grown in Woramit Agricultural Research Center and in the Adet Agricultural Research Center were statistically different ($P \leq 0.05$). On the other hand, the cup quality parameters of coffee varieties grown in Woramit and in Adet were not statistically different at probability values of $P \leq 0.05$. In WARC, Buno wash, Wush Wush, and Ababuna coffee varieties showed better physical quality in terms of 100 bean weight, bean length, bean width, and screen size, while varieties Buno wash and Wush Wush showed better physical quality only in terms of 100 bean weight and bean length in AARC. Cup quality of coffee varieties grown in WARC was ranged from 48.16% to 51.33% while that of coffees grown in AARC was from 45.00% to 50.83%. Total coffee quality in WARC was at the range of 85.50–89.33% while in AARC at the range of 81.66–87.83%. Generally, the total coffee qualities of all the tested varieties in both locations were within the standard of the Ethiopian Commodity Exchange for coffee where the quality of coffee in WARC was relatively better than that of coffee in AARC. Therefore, in terms of quality, all the tested varieties of coffee can be used to produce coffee in both study areas and areas with similar agroecology of the Amhara Region, Ethiopia. Further research on the yield performance of the coffee varieties is also recommended.

Data Availability

The data availability statement is correct in which it is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

Melese Wale has conceived and designed the experiments, analyzed the data, and wrote the manuscript. Melkamu Alemayehu and Abrar Sualeh have designed the experiment and commented and edited the manuscripts. All authors approved the manuscript.

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