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Research Article

# Growth Characteristics and Yield Performance Evaluation of Hybrid Coffee (*Coffea Arabica L.*) Genotypes in Sidama, Southern Ethiopia

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## Abstract

Ethiopia is the center of origin and has a varied genetic foundation for Arabica coffee, but there is still a lack of yield-competitive enhanced varieties, which is why the average productivity in the country is significantly lower than the global average. The average national productivity is quite low as a result. Ethiopia's pure line variety development program has shown that it is rarely possible to increase yield over 1800–2000 kg/ha through direct selection. This suggests that heterotic hybrids are needed to maximize yield up to 2500–3000 kg/ha. Therefore, in order to find high yielding hybrids, it may be helpful to further assess the performance of the best performing hybrids for yield and growth traits at full bearing stage. Therefore, creating hybrid coffee kinds that are stable, disease-resistant, and high yielding is crucial to closing this gap and increasing coffee productivity. Thus, assessing coffee hybrid genotypes for yield and yield components was the goal of this study. To illustrate the growth and yield characteristics of four promising hybrid genotypes of Arabica coffee, the experiment was carried out at Awada and Leku. A randomized complete block design (RCBD) with three replications was used to carry out the experiment between 2016 and 2021. Data were gathered on plant height, number of primary and secondary branches, length of the longest primary branch, number of main stem nodes, stem girth, internode length on the main stem, canopy diameter, and yield per hectare. The findings showed that there were statistically significant differences between the growth features. The number of primary branches (52.08 – 58.83), number of secondary branches (148.23 – 179.25), number of major stem nodes (27.96 – 30.66), stem diameter (2.82 – 3.45cm), canopy diameter (199 – 221.77cm), and average length of primary branches (107.00 –116.84cm) are all reported. According to the study's findings, the hybrid 75227x1681 (3491 kg/ha) produced the highest overall yield per hectare, followed by 75227xAngafa (3023kg/ha) cultivated at Awada and 75227X1681 (1437kg/ha) in Leku. There will be a greater probability of obtaining enhanced Arabica coffee hybrid varieties in the south Ethiopian growing environment because the potential hybrid genotypes outperformed the current improved varieties at Awada and Leku. In order to suggest a stable and appropriate hybrid variety for coffee growers in the South, the experiment should be conducted again at various representative trial sites.

## Keywords

Coffee, Hybrids, Growing Characteristics, Clean Coffee

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# 1. Introduction

The most traded tropical agricultural product in the world is Arabica coffee [21], with oil coming in second [30, 36]. Up to 25 million farming households worldwide produce 80 percent of the world's coffee, making it the most traded tropical product [11, 12]. In addition to making a significant contribution to foreign exchange as a primary cash crop in many producing nations, it provides millions of people with a living [32]. For millions of people in coffee-growing nations in Africa, Asia, and Latin America, it is a significant source of income [26].

Ethiopia is renowned among African nations for producing Arabica coffee (C arabica), which is prized for its exceptional quality, distinct flavor, and aroma [25].

The mountains in the southwest of Ethiopia are where Coffea arabica originated and where its genetic variety was concentrated [5, 9, 14, 17, 31]. Ethiopia's most significant gift to the world is coffee, which has had and continues to have a profound economic, social, and spiritual influence on a wide range of individuals from various geographic areas, cultural backgrounds, and personality types. Almost daily, sometimes twice a day, or more, it is one of the most valued international beverages.

Ethiopia's primary source of foreign exchange profits is coffee, which generates US$1.4 billion annually and accounts for almost 35% of all major export commodity earnings [12, 35]. Coffee also makes up a significant portion of the country's foreign currency income [8]. Ethiopia has a favorable climate for coffee production, with the right amount of rainfall, soil type, altitude, temperature, and pH. According to [7], the nation is the origin of Coffea Arabica and has a genetic background for Arabica coffee that is quite heterogeneous. Ethiopia has the ability to sell a significant number of specialty coffees and generates a variety of unique Arabica coffees [27]. Ninety five percent of Ethiopia's coffee is grown by smallholder farmers [4, 22].

The dearth of high-yielding, disease-resistant hybrid cultivars that are best suited to the region's current environmental conditions has significantly limited coffee production in Ethiopia overall and in the southern region in particular. In Coffea Arabica, heterosis has been reported in a number of studies [7, 29, 37], with hybrid F1 cultivars accounting for an average of up to 30%. A hybridization project was started in 1996 GC with the goal of creating high-yielding coffee hybrids that are resistant to coffee berry disease (CBD) and have the typical quality of Sidama and Gedeo coffee.

A maximum over best parent heterosis of 44.6% for yield was found for the 15 hybrids under study based on a number of observations conducted since 1998. Eight of these fifteen hybrids demonstrated an average production of more than 15 kg/ha of clean coffee, significantly above the performance of the experiment's routine checks [38]. Lastly, four of these eight hybrids (744xAngafa, 7440xAngafa, 75227xAngafa, and 75227X1681) are being encouraged for additional research to validate their performance over time at Sidama Region under Awada & Leku growing conditions.

A variety must be suited to a region because a variety or hybrid may adapt and satisfy the commercial interest in one coffee-growing region but may not be appropriate for use in another due to environmental factors like soil, temperature, humidity, and rainfall [20, 33]. In Ethiopia, the selection and breeding process is tailored for each locality using local landraces and crosses from the specific place in order to reduce adaptation issues and prevent the blending impacts of coffee from known quality growing areas with coffee from another area or locations.

Similar to this, southern Ethiopia is one of the best places to cultivate high-quality coffee. Research is being done at the Awada Agricultural Research Sub Center and its trial sites to create coffee types that are suitable for the region's growing conditions. Thus, the purpose of this experiment was to ascertain the hybrid coffee variety's growth traits and yield performance.

# 2. Material and Methods

## 2.1. An Explanation of the Research Area

During the 2016–2021 cropping seasons, the experiment was carried out on a trial plot of the Leku trial site substation and the Awada agricultural research sub-center (AARSC). The mid-highland agroecology of Awada is tepid to cool semi-arid. Situated in the Sidama Region, approximately 43 kilometers south of Hawassa and 315 kilometers south of Addis Ababa, at 603' N latitude and 380 E longitude, and at an elevation of roughly 1750 m.a.s.l., it is close to Yirgalem town. With two wet and dry seasons and an average annual precipitation of 1342 mm, the region exhibits a semi-bimodal rainfall distribution [1]. The average yearly air temperature is between 11 ℃ and 28.40 ℃. The sub-center's primary soil types are chromotic-cambisols and eutric-nitosols, both of which are excellent for growing coffee [25]. The Leku trial site is located at an altitude of 1805 m.a.s.l. of. According to the country's coffee-growing agroecology, the experimental site (Awada) is classed as mid-altitude, while the remaining experimental site (Leku) is defined as high land [1].

## 2.2. Design and Treatment of Experiments

Three common check cultivars and four promising hybrids of Arabica coffee, whose progenitors were from south and southwest Ethiopia, were employed as a treatment (Table 1). Using a randomized complete block design (RCBD) with three replications, normal and healthy seedlings were planted in experimental plots in 2016. Each plot included 20 trees spaced 2 m by 2 m apart. All standard management procedures were rigorously and consistently implemented for every plot [10].

*Table 1. Description of experimental coffee genotypes.*

| No | Arabica Coffee Hybrid genotypes | Designation | Germplasm composition | Cross category |
|---|---|---|---|---|
| 1 | 744xAngafa | Arabica Coffee Hybrid | SWEXSE | $CBD_R$ xHY+Q |
| 2 | 7440xAngafa | Arabica Coffee Hybrid | SWEXSE | $CBD_R$ xHY+Q |
| 3 | 75227xAngafa | Arabica Coffee Hybrid | SWEXSE | $CBD_R$ xHY+Q |
| 4 | 75227x1681 | Arabica Coffee Hybrid | SWEXSE | $CBD_R$ xHY+Q |
| 5 | Feyata | Released Arabica coffee pure line check variety | SE | $CBD_R$xHY |
| 6 | Ababuna | Released Arabica Coffee Hybrid check Variety | SWEXSWE | HY+Q |
| 7 | Angafa | Released Arabica coffee pure line check variety | SE | HY+Q |

Whereas: SWE=South west Ethiopian coffee type, SE=South Ethiopian coffee type, $CBD_R$=Coffee berry disease resistance, HY=High yielder, Q=Quality.

## 2.3. Data Collection

Using the standard IPGRI procedures, data for eight growth characteristics were recorded from each treatment during the study period: plant height, number of primary and secondary branches, length of the longest primary branch, number of main stem nodes, stem girth, internode length on the main stem, canopy diameter, and average yield over three years.

Each character's data was gathered using the following methodology: A pocket meter was used to measure the height of the plants in cm from the base to the tip.

Using a Vernier caliper, the stem girth was measured in centimeters at ground level, or five centimeters above the ground. A pocket meter was used to measure the canopy's diameter in centimeters from east to west and north to south. The average was then calculated.

Total plant height (TPH) - height up to first primary branches (HUFPM) / Number of main stem nodes (NMSN) was used to compute the internode length on the main stem.

Counting the number of principal branches allowed for the recording of this character.

Number of secondary branches: the number of secondary branches was counted in order to record this character. Using a pocket meter, the length of the longest primary branch was measured in meters. The number of nodes on the main stem was counted in order to determine the number of main stem nodes. Yield: The weight of the fresh cherry and the dried cherry (buni) yield per plot were measured in grams. The dried cherry yield was converted to fresh cherry by multiplying it by 2.6 as a correction factor, and then it was converted to kilograms per hectare [18].

## 2.4. Analysis of Data

The SAS statistical software package (version 9.3) was used to analyze the data, and the Least Significant Difference (LSD) Test procedure was used to compare the mean values at the 5% level of significance [18].

## 2.5. Estimating Heterosis

Based on the superior parent and heterosis, the hybrid performance for every cross combination was assessed. Using the approach, the percentage of heterosis was determined for the characters exhibiting significant differences for crosses. Heterobeltosis, or best-parent heterosis: It alludes to how much better the F1 hybrid performs than its finest parent.

# 3. Results and Discussion

## 3.1. Clean Coffee Yield

According to the overall mean analysis of variance (ANOVA), there was a significant difference between the genotypes' yield potential (Table 2). Crosses 75227*1681 had the highest three-year mean output (2464 kg/ha), whereas crosses 744* Angafa produced the lowest three-year mean yield (1897 kg/ha). Ababuna produced the lowest yield of 1271 kg/ha among the standard tests, whereas Angafa recorded the best three-year mean yield of 1630 kg/ha (Table 2).

According to the individual location analysis, crosses

75227*1681 produced the highest three-year mean yield (3491 kg/ha), while crosses 744* Angafa at Awada produced the lowest three-year mean yield (2602 kg/ha). Ababuna produced the lowest yield of 1573 kg/ha at Awada, whereas Angafa recorded the highest three-year mean yield of 2095 kg/ha among the standard tests. The Leku site's mean yield data result showed that crosses 75227X1681 had the highest three-year mean yield (1437 kg/ha), while crosses 744X Angafa had the lowest three-year mean yield (1192 kg/ha). Ababuna produced the lowest yield of 800 kg/ha at Leku, while Angafa had the best three-year mean yield of 1166 kg/ha among the standard checks (Table 2). In the future coffee development program, the occurrence of adequate variety among the analyzed materials presents a huge chance to bring about significant improvement through cross-breeding and selection. Earlier authors reported significant genetic variability in arabica coffee for growth, disease resistance, and yield [16, 18, 23, 24, 34], which was consistent with the significant yield difference found in this study.

## 3.2. Growth Characters

With the exception of the number of main stem nodes, the number of secondary branches, and the average length of primary branches, all quantitative features analyzed under Awada and Leku growth conditions shown significant (P<0.05) variance among coffee hybrids (Tables 3 and 4).

The plant's overall height (1.99–2.45 m), stem diameter (2.72–3.45 cm), canopy diameter (199.10 –221.77 cm), number of main stem nodes (27.96–49.79), inter node length on the main stem (7.13– 9.04 cm), number of primary branches (52.08–59.21), number of secondary branches (148.25–179.25), and average length of primary branches (107.00–116.84 cm) are some of the morphological and growth characteristics analyzed at Awada (Table 3).

The plant's overall height (2.71–3.07 cm), stem diameter (5.20–5.42 cm), canopy diameter (191.33–219.00 cm), number of main stem nodes (30.60–34.33), inter node length on the main stem (6.06–8.66 cm), number of primary branches (55.13–66.93), number of secondary branches (99.00–108.46), and average length of primary branches (107.33–115.33 cm) are all displayed in Table 4's morphological and growth characteristics for Leku. There is a great opportunity to greatly progress the future coffee variety creation program through cross-breeding because there is adequate variance among the materials under examination. In line with the findings of previous authors, this study found a significant difference for the quantitative features that were measured [2, 3, 19, 28, 24, 15, 34].

*Table 2. Mean yield of clean coffee (Kg/ha) of hybrids and their checks at Awada and Leku Location.*

| Candidate hybrids and checks | Awada | | | | | Leku | | | | | Over all mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | Mean | Survival rate (%) | 2019 | 2020 | 2021 | Mean | Survival rate (%) | |
| 75227 x Angafa | 2109 | 4442 | 2520 | 3023 | 90 | 828 | 1854 | 1258 | 1313 | 100 | 2168 |
| 744 x Angafa | 2152 | 3713 | 1942 | 2602 | 96 | 867 | 1573 | 1134 | 1192 | 100 | 1897 |
| 75227 x 1681 | 3189 | 4976 | 2309 | 3491 | 100 | 660 | 2679 | 971 | 1437 | 100 | 2464 |
| 7440 x Angafa | 2639 | 3942 | 2272 | 2951 | 100 | 729 | 1987 | 1289 | 1335 | 100 | 2143 |
| Checks | | | | | | | | | | | |
| Ababuna | 696 | 2953 | 1070 | 1573 | 100 | 999 | 1106 | 800 | 968 | 100 | 1271 |
| Feyate | 707 | 4032 | 1086 | 1941 | 100 | 693 | 2257 | 974 | 1308 | 100 | 1625 |
| Angafa | 1305 | 3447 | 1534 | 2095 | 100 | 682 | 1530 | 1285 | 1166 | 100 | 1630 |
| LSD | 2.97 | 8.11 | 10.03 | 4.44 | | 8.27 | 8.21 | 5.33 | 4.32 | 100 | 2.56 |
| CV | 9.12 | 11.61 | 30.99 | 9.88 | | 59.64 | 24.88 | 27.21 | 19.49 | 100 | 7.64 |
| Sig. | *** | ** | * | *** | | Ns | * | Ns | Ns | | *** |

*Table 3. Mean growth characteristics of hybrids and their checks at Awada location.*

| Candidate Hybrids and Checks | Height (m) | Canopy diameter (cm) | Stem girth (cm) | No. of nodes on the main stem | Inter node length on the main stem (cm) | No. of primary branches | No. of secondary branches | Length of first primary (cm) |
|---|---|---|---|---|---|---|---|---|
| 75227 x 1681 | 2.27ab | 221.77a | 3.43ab | 30.96ab | 8.75ab | 53.62b | 169.25ab | 115.833ab |
| 75227 x Angafa | 2.24ab | 210.02bc | 3.21abc | 29.04ab | 8.52ab | 55.08ab | 179.25a | 116.837a |
| 7440 x Angafa | 2.45a | 216.02ab | 3.45a | 29.88ab | 9.04a | 58.46a | 173.92ab | 113.753ab |
| 744 x Angafa | 2.42a | 209.02bc | 3.13bcd | 30.66ab | 8.15ab | 58.83a | 173.33ab | 111.543abc |
| Feyate | 2.24ab | 211.87ab | 2.72e | 29.46ab | 8.00ab | 55.87ab | 178.34a | 113.963ab |
| Angeffa | 2.44a | 206.23bc | 3.07cd | 49.79a | 7.93ab | 59.21a | 148.25b | 109.75bc |
| Ababuna | 1.99b | 199.10c | 2.82de | 27.96b | 7.13b | 52.08b | 167.46ab | 107.00c |
| Mean | 2.294 | 210.57 | 3.12 | 31.68 | 8.22 | 56.19 | 169.97 | 112.66 |
| CV | 7.34 | 2.92 | 5.62 | 26.62 | 11.83 | 4.64 | 8.58 | 3.18 |
| LSD | 0.2998 | 10.97 | 0.314 | 15 | 1.73 | 4.64 | 25.956 | 6.37 |

Whereas **, is significant at P < 0.01, ***, is significant at P < 0.001 and ns = not significant at P ≤ 0.05.

*Table 4. Mean growth characteristics of hybrids and their checks at Leku location.*

| Candidate Hybrids and Checks | Plant height (m) | Canopy diameter (cm) | Stem girth (cm) | Number of nodes on the main stem | Inter node length on the main stem (cm) | No. of primary branches | No. of $2^0$ branches | Length of longest primary (cm) |
|---|---|---|---|---|---|---|---|---|
| 75227x1681 | 2.8967ab | 210.83abc | 5.34ab | 31.93 | 7.46ab | 61.2ab | 99.00 | 108.00 |
| 75227 x Angafa | 2.7533ab | 191.33c | 5.2ab | 30.60 | 6.06b | 55.13b | 108.46 | 108.00 |
| 7440 x Angafa | 3.0667a | 204.17abc | 5.38ab | 34.33 | 7.66ab | 66.93a | 107.86 | 107.33 |
| 744 x Angafa | 2.9633ab | 216.33ab | 5.36ab | 32.80 | 6.86ab | 62.53ab | 101.33 | 111.80 |
| Feyate | 2.9433ab | 218.33a | 5.09ab | 31.26 | 7.40ab | 61.73ab | 106.46 | 114.00 |
| Angeffa | 2.92ab | 219.00a | 5.42a | 33.66 | 8.66a | 66.40a | 101.40 | 115.33 |
| Ababuna | 2.7067b | 195.67bc | 4.82 | 31.20 | 6.20b | 59.33ab | 102.13 | 108.66 |
| Mean | 2.8928 | 207.95 | 5.23 | 32.25 | 7.19 | 61.89 | 103.80 | 110.44 |
| CV | 6.80 | 6.06 | 6.12 | 7.64 | 17.89 | 8.90 | 7.55 | 4.08 |
| LSD | 35.23 | 22.42 | 0.56 | NS | 2.28 | 9.82 | NS | NS |

Whereas **, is significant at P < 0.01, ***, is significant at P < 0.001 and ns = not significant at P ≤ 0.05.

## 3.3. Estimation of Heterosis

Heterosis was found for the yield character examined when comparing the analysis of heterosis to the superior parent. For yield best parent heterosis, the estimated heterosis as a percentage of yield varied from 16.48 to 43.44% (Table 5). Crosses 75227x1681 had the highest best parent heterosis (43.44%), followed by crosses 75227xAngafa (33.27%), and crosses 744xAngafa had the lowest best parent heterosis (16.48%). For this specific characteristic, the overall heterosis manifestation magnitude was good. The findings of earlier researchers [6, 13, 38] who documented a greater magnitude of better-parent heterosis for this trait are consistent with our conclusion. Differences in the parental lines involved and the experiment's setting are most likely the main causes of the discrepancies between the current and earlier findings.

*Table 5. Heterosis parameters in yield of hybrid Arabica coffee.*

| Hybrids and checks | Best parent heterosis |
|---|---|
| 75227xAngafa | 33.27 |
| 744xAngafa | 16.48 |
| 75227x1681 | 43.44 |
| 7440xAngafa | 31.57 |
| Checks | |
| Ababuna | |
| Feyate | |
| Angafa | |

## 4. Summary and Conclusion

Ethiopia's economy depends heavily on coffee. About 15 million Ethiopians, or four million smallholder families, or sixteen percent of the country's total population, depend on coffee production for their livelihood. Coffee is the main source of income for a large number of these growers. Therefore, increasing productivity and production is crucial to helping coffee growers. In order to ascertain the hybrid coffee variety's growth characteristics and yield performance, the current experiment was carried out. Ethiopia's pure line variety development program has shown that it is rarely possible to increase yield over 1800–2000 kg/ha through direct selection. This suggests that heterotic hybrids are needed to maximize yield up to 2500–3000 kg/ha. To find high-yielding hybrids for commercial usage, it may be helpful to further assess the performance of the top-performing hybrids for growth and yield characteristics. To find and suggest hybrid genotypes of Arabica coffee for coffee-growing regions in southern Ethiopia, growth traits and yield performance were considered.

In light of this, the promising Arabica coffee hybrid 75227x1681 (3491 kg/ha) and 75227x Angafa (3023 kg/ha) outperformed the current improved varieties in the Awada growing environment. In the Leku growing environment, the hybrid 75227X1681 (1437 kg/ha) and 7440XAngafa (1335 kg/ha) outperformed the current improved check varieties. As a result, the likelihood of obtaining better Arabica coffee types for the growing conditions in Awada and Leku is higher. Therefore, before developing improved hybrid varieties, more package development studies for the most promising hybrids must be conducted side by side in order to increase production and productivity at Awada and Leku as well as the same growing environment.

Much work has not been done to take advantage of the potential in germplasm diversity to create superior hybrids and pure-line selections for the region, despite the enormous potential that exists within coffee populations in the Sidama and Gedio areas in southern Ethiopia and the encouraging heterosis results reported from the crosses among elite coffee lines selected from this area. The current study made it abundantly evident that hybrid breeding could result in notable advancements. Therefore, in order to create higher-yielding and better-performing hybrids for the region, a continual crossing program is needed to obtain a large number of cross combinations for thorough and in-depth examination.

## Abbreviations

| | |
|---|---|
| AARCS | Awada Agricultural Research Sub-Center |
| WGARC | Wondo Genet Agricultural Research Center |
| JARC | Jimma Agricultural Research |

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## Conflicts of Interest

No conflicts of interest are disclosed by the authors.

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