

Agronomic and Cherry Characteristics of 10 Yellow Arabica Coffee (*Coffea arabica* L.) Accessions Grown at Different Altitudes in Temanggung

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ABSTRACT

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Yellow fruited Arabica coffee is a rare genetic variant with high potential for specialty coffee production, yet its agronomic performance remains poorly documented, particularly under different altitude conditions. This study aimed to evaluate the agronomic traits and cherry characteristics of ten yellow Arabica coffee (*Coffea arabica* L.) accessions grown at varying altitudes in Temanggung Regency, Central Java, Indonesia. The research was conducted as a descriptive exploratory quasi-field experiment across three altitude ranges: 1101–1300, 1301–1500, and >1501 masl. Observations included qualitative fruit characteristics based on IPGRI (1996) descriptors and quantitative agronomic traits related to productivity and flavor determinants, such as cherry brix content, water content, pH, fruit and bean dimensions, yield components, and peaberry occurrence. The results revealed substantial variation among accessions in both agronomic and fruit characteristics, indicating strong genotype environment interactions, particularly with altitude. Accessions grown at higher altitudes generally exhibited higher brix values, larger fruit and bean sizes, and improved green bean weight, reflecting enhanced flavor potential and productivity. Several accessions also showed unique qualitative traits, such as distinct ripe fruit color and fruit disc type, which are valuable phenotypic markers for genotype differentiation. Overall, the findings demonstrate that yellow Arabica coffee accessions in Temanggung possess considerable agronomic diversity and production potential, highlighting their suitability for further selection and development as local superior clones to support sustainable specialty coffee cultivation.

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1. Introduction

Arabica (*Coffea arabica* L.) coffee is a type of coffee that is widely popular and consumed by various groups in the world[1], This makes the percentage of Arabica coffee cultivation in the world high, ranging between 60% of the world's total coffee production[2]. Arabica coffee has a distinctive taste when compared to the 3 types of coffee that are often consumed, namely the Robusta, Excelsa and Liberica variants, arabica coffee is more often used as a specialty coffee, so

that the selling price is more expensive than other variants. High demand makes Arabica coffee production and the variety of Arabica coffee variants high and increasing every year. To increase production and also Arabica coffee variants, this can be achieved through a program such optimize cultivation culture on land and plant breeding activities[3].

Several studies state that the genetic diversity of Arabica coffee is much lower than Robusta coffee[4]. This is not due to the propagation method used, but because most of the variants are autogamy, a unique evolutionary pattern, and due to domestication patterns. This indirectly has consequences for the choice of coffee variants which influence the types of flavors that can be consumed. One way to gain superior individual and increase diversity is by selecting local accessions (indigenous varieties) or landrace[5]. Through this selection, it is hoped that coffee accessions will be obtained that have undergone changes or mutations due to various factors. Genetic changes or new variants of Arabica coffee can be predicted to produce different flavors[6]. Different genotypes in coffee affect the chemical compounds produced which affect the taste of the coffee[7].

There are Arabica coffee variants that are rarely developed and cultivated, but have the potential for a unique taste compared to other Arabica coffee variants, that is Arabica coffee with a yellow cherry ripe skin color. which, in general, ripe coffee cherries are usually red in color. Yellow Arabica coffee is not the Arabica coffee that commonly consumed and has a designation for higher specialty coffee[8]. Arabica coffee varieties that have yellow ripe skin and already known are the yellow bourbon and yellow catura/catuai. Yellow catura and yellow bourbon coffee obtained from a genetic mutation of the Arabica bourbon coffee variant which originally from Brazil[9]. Yellow catura and bourbon Arabica coffee have a different taste from red skinned Arabica coffee, especially from the higher sweet sensation, has a more dominant tropical taste, and has a medium to light body [10]. The uniqueness of this coffee makes it have a high price and is popular with coffee lovers.

Temanggung Regency is one of the areas that produces good quality Arabica coffee in Central Java[11] and even the world. This is proven by Temanggung's achievements in the coffee festival in Atlanta, United States in 2016 by becoming a champion[12]. This is because, among other things, Temanggung has geographical conditions, especially the altitude, which supports the cultivation of Arabica coffee, so that the quality is very competitive. Arabica coffee grows and produces optimally at altitudes above 1000 meters above sea level[13]. In Temanggung, the altitude above 1000 meters above sea level is in the western part which is the slope of Mount Sindoro and Sumbing. A small number of Arabica coffee farmers spread across Temanggung Regency have begun cultivating yellow Arabica coffee, both with varieties that are clearly known and also those that have not been identified.

With the existence of a yellow Arabica coffee population in Temanggung, a study should be conducted to assess its agronomic traits and cherry/fruit characteristic at various altitudes, in order to be used as an initial study to map the genetic diversity of Arabica coffee, especially emphasizing production capacity, because the fruit/cherry that containing the seeds is the generative part harvested and consumed. Several accessions that have not been identified or originate from local mutations, but have good production potential, can be used as local superior clones.

2. Method

The research was conducted in Temanggung Regency, Central Java Province, Indonesia, specifically on coffee plantations in the districts of Tlogomulyo, Ngadirejo, Candiroto, and Bansari for fruit character observation and observation of agronomic data on coffee taste determinants was carried out in the biotechnology and plant breeding laboratory of Tidar University. The research was conducted from September 2025 to January 2026. The tools used in this study include rulers, vernier calipers, altimeter, knives, razor blades, magnifying glasses, counters, digital cameras with macro lenses, digital scales, analytical scales, mortar pestles, digital refractometers, digital pH meters, and digital moisture analyzers. The materials used include fruit and flower samples from 10 selected Temanggung yellow coffee accessions.

2.1. Research Methods

The research conducted was a descriptive exploratory study aimed at determining the potential agronomic properties and characteristics of yellow Arabica coffee fruit in various locations and altitudes in Temanggung. The altitude was divided into three stratifications: 1101-1300, 1301-1500, and >1501 masl. Because the altitude of the site cannot be randomized, the plants grow in the field, and each field is at a different specific altitude, the research is a quasi-field experiment[14] with the main factor (factor A) being location/altitude and the second factor (factor B) being genetics/accession. Each variable observed in the accession was 5 replications. This method is suitable for observing accessions whose position cannot be changed/in the natural environment and for main factors that cannot be randomized[15]. The first research activity carried out was to conduct a location survey and search for Arabica coffee accessions. The accessions found were then identified by identifying the location where the accessions grew and its altitude. Fruit characteristic data will be presented in a character table and agronomic trait data will be presented in the form of a Duncan test table.

2.2. Research Implementation

The first research activity carried out was to conduct a location survey and search for Arabica coffee accessions. The accessions found were then identified by the location of the accession's growth and altitude. Data collection of fruit characters and several agronomic traits was carried out directly in the field when entering the harvest/ripening period of yellow Arabica coffee fruit. Next, samples of ripe fruit were taken as many as 100 fruits per accession, so that with 5 replications, there were 500 ripe fruits taken for further observation of agronomic traits in the laboratory.

2.3. Observation Variables

The variables observed in this study were divided into two main parameters, namely agronomic traits and fruit characteristics. The agronomic traits parameters consisted of cherry brix content (Brix), cherry water content (%), water pH and cherry mucilage, crop load, number of flowers per axil, number of flowers per fascicle, internode distance (cm), fruit length (mm), fruit width (mm), seed length (mm), seed width (mm), seed thickness (mm), weight of 100 cherries (gr), weight of 100 green beans (gr), number of peaberries, number of flowers per primary branch, number of berries per primary branch, number of seeds per berry. Meanwhile, fruit characteristics included fruit ripeness color, fruit shape, presence of fruit ribs, endocarp texture, fruit disc shape, and pulp thickness. Fruit characteristic parameters were collected by scoring data based on character groups referring to the descriptor guidelines from IPGRI[16].

3. Results and Discussion

The yield of coffee fruit and beans is an important parameter to determine the superiority of coffee varieties[17], moreover, coffee is one of the plantation commodities whose quality is assessed based on the taste that exists after being processed into a ready to consume product. so that the factors that determine taste and productivity are important to analyze in order to set a superior accessions and their interactions with environmental factors, especially altitude which is a specific requirement for the growth and production of Arabica coffee[18]. In this study, yellow Arabica coffee grown in Temanggung was found to grow optimally at altitudes above 1000 masl as can be seen in Table 1. As we understand, yellow Arabica coffee found in Temanggung grows at a minimum altitude in Tlogomulyo with an altitude of 1,187.55 masl and the highest in Bansari with an altitude of 1,833.98 masl. Altitude can influence variations in environmental conditions for growing plant[19], especially Arabica coffee plants which are sensitive to altitude.

Table 1. Altitude information of accession

No.	Altitude Groups (masl)	Accession	Location	Altitude (masl)
1.	1101-1300	Accession 1 (Tgl_2_4)	Tlogomulyo	1.187,55
2.	1101-1300	Accession 2 (Tgl_2_5)	Tlogomulyo	1.187,55
3.	1301-1500	Accession 3 (Cdr_1_5)	Candiroto	1.476,17
4.	1301-1500	Accession 4 (Cdr_2_5)	Candiroto	1.371,4
5.	1301-1500	Accession 5 (Cdr_3_1)	Candiroto	1.374,02
6.	1301-1500	Accession 6 (Ngd_2_3)	Ngadirejo	1.388,99
7.	1301-1500	Accession 7 (Ngd_3_4)	Ngadirejo	1.425,3

8.	>1501	Accession 8 (Bns_1_1)	Bansari	1.592,06
9.	>1501	Accession 9 (Bns_2_5)	Bansari	1.833,98
10.	>1501	Accession 10 (Bns_3_5)	Bansari	1.632,34

Several previous studies have stated that the altitude at which Arabica coffee is grown has an influence on the taste of Arabica coffee. This is caused by temperature dynamics which indirectly affect the rate and degree of fruit ripening, most fruits will experience a longer ripening period as the growing altitude increases, because the air temperature will become colder, thus slowing down the metabolic process. As an example and comparison, for red-fruited Arabica coffee Borbor, Timtim, and Ateng Super, the optimal height for production and yield is in the range of 1200-1400 meters above sea level and the lowest is at an altitude of 1000-1200 meters above sea level[20]. In non-climacteric coffee cherry, the ripeness of the fruit on the tree is a crucial factor in determining its quality. The longer ripening time at higher altitudes allows Arabica coffee cherries sufficient time to develop a more complex flavor structure due to increased acidity, an optimized flavor profile, the accumulation of sugars, and organic acids when compared with coffee grown in the lowlands which usually has a more bitter and bland taste. There is limited data and research on the effect of altitude on the agronomic traits and character of yellow Arabica coffee cherries.

3.1. Cherry Characteristics of Yellow Arabica Coffee

Coffee cherries are an important part that is harvested when entering the coffee harvest season, the characteristics of coffee cherries can be used as a description to determine the cultivar or variety of coffee[21]. Although there is no specific research that directly states that coffee fruit qualitative morphology has an influence on taste and quality, however, the quantitative morphological characteristics of the fruit can indirectly influence the taste and quality of the coffee. Well identified fruit characteristics can be used as markers of phenotypic differences between accessions. Yellow Arabica coffee identified in Temanggung shows differences in both qualitative and quantitative characteristics, which can be visually observed in Table 2.

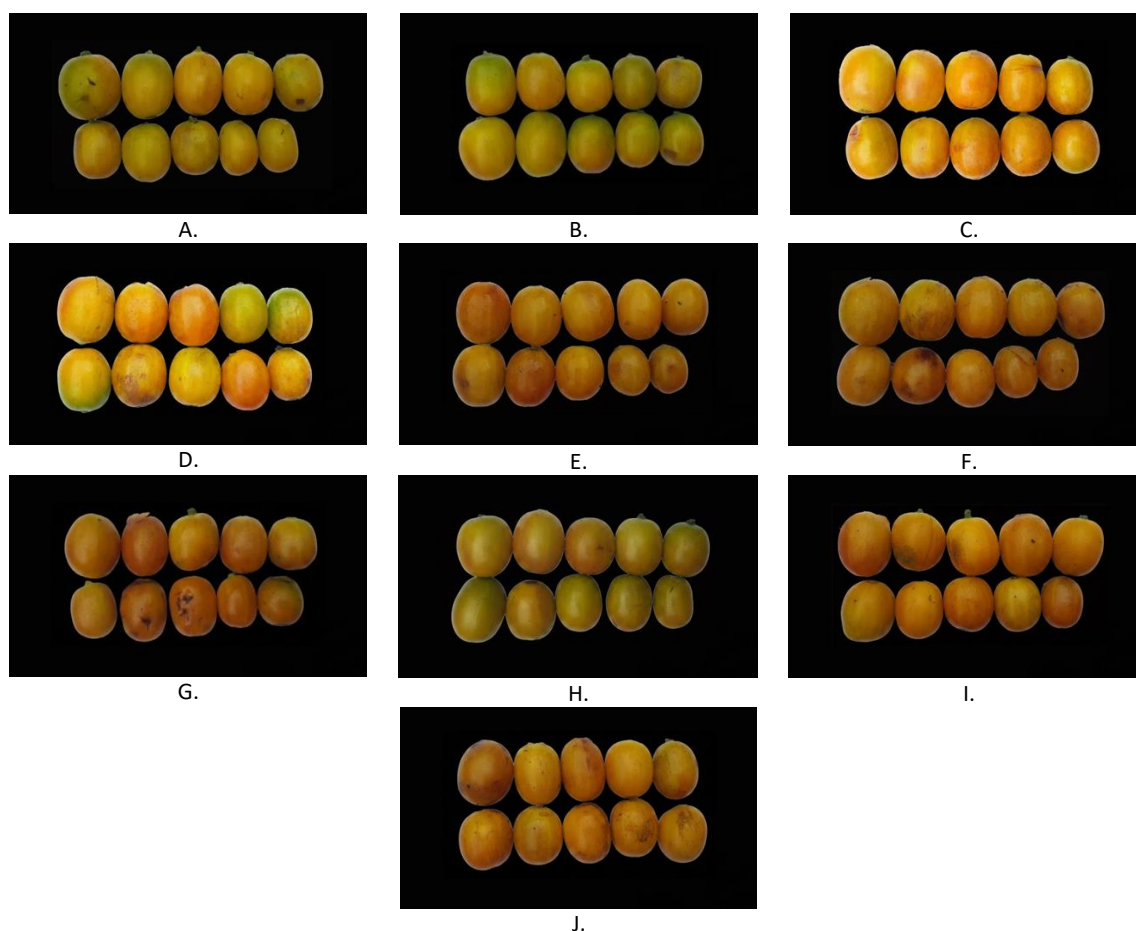


Fig. 1. Cherry shape and ripe color of coffee accessions: A. Accession 1 (Tgl_2_4), B. Accession 2 (Tgl_2_5), C. Accession 3 (Cdr_1_5), D. Accession 4 (Cdr_2_5), E. Accession 5 (Cdr_3_1), F. Accession 6 (Ngd_2_3), G. Accession 7 (Ngd_3_4), H. Accession 8 (Bns_1_1), I. Accession 9 (Bns_2_5), and J. Accession 10 (Bns_3_5)

Visually, as can be seen in Figure 1, it can be understood that in terms of fruit shape and color, there are differences between accessions. The most dominant ripe cherry color is orange. There are 6 accessions that are orange, 3 that are semi-orange yellow, and 1 that is yellow. Variations in the ripe color of coffee cherries do not directly affect the sweetness level of the cherries, but based on this study, coffee with an orange ripe color has a much higher sugar content than red fruit in Indonesia which only averages between 7-12 brix. The endocarp texture of the yellow Arabica coffee accession consists of coriaceous and sub-coriaceous type. The thickness of the pulp or mesocarp affects the taste of coffee made using the wine method[22], because in the manufacturing/drying process, the skin is not peeled or processed with the skin, the thick pulp provides a fresh, sour taste and a unique aroma similar to a stronger wine but without alcohol content, this is because during the drying process the liquid and sugar in the pulp can penetrate the beans as fermentation occurs over a long period of time. In this study, there were only 2 accessions with thick pulp, namely accessions 6 and 7.

Table 2. Qualitative and quantitative morphology of coffee accessions

Character	Accessions									
	1	2	3	4	5	6	7	8	9	10
Ripeness color	Orange yellow	Yellow	Orange	Orange yellow	Orange	Orange	Orange	Orange yellow	Orange	Orange
Fruit shape	Elliptic	Round	Elliptic	Round	Round	Round	Obovate	Elliptic	Round	Oblong
Fruit ribs	Present	Absent	Present	Present	Present	Present	Present	Absent	Present	Present
Endocarp texture	Coria..	Coria..	Coria..	Coria..	Sub-coria..	Sub-coria..	Coria..	Coria..	Coria..	Coria..
Fruit disc	Marked	Cylindri..	Cylindri..	Marked	Unmark.	Unmark.	Cylindri..	Beaked	Cylindri..	Beaked
Pulp thickness	Thin	Mid	Mid	Thin	Thin	Thick	Thick	Mid	Thin	Mid

Although quantitative morphological traits are influenced by the environment, because it interact and is influenced by the expression of many genes or polygenic, so that the appearance becomes varied or dynamic depending on environmental conditions. Qualitative morphological traits such as ripe fruit color as in Fig 2 and shape are not greatly influenced by environmental factors, because the qualitative characteristics of plants are regulated by a few genes but with high penetrance, so that their expression is more dominated by the genotype, not the interaction of the genotype and the environment. This confirms that several fruit characters, especially qualitative ones, can be used to differentiate genotypes between yellow Arabica coffee accessions identified by fruit morphology. Local accessions are more susceptible to genotypic changes and mutations due to long-term environmental adaptation, genetic drift, and human intervention, especially selection[23].



Fig. 2. Accessions with different ripe colors: A.Yellow semi orange ripe color and B. Orange ripe color

3.2. Agronomic Characteristics of Yellow Arabica Coffee Accessions

Coffee agronomic characteristics, especially those related to the expression of genes that determine flavor and productivity, are important considerations in selecting and breeding coffee plants, because it is related to the quality of the products and economic orientation. In a study conducted by identifying 18 agronomic characters, only one character showed no significance for the type of accession, that is crop load. This can also be caused by the production capacity of each accession interacting with the environment and each primary branch does not have a definite pattern of fruit numbers. Based on the 17 traits that showed significance, it can be understood that the yellow Arabica coffee accessions in Temanggung have clear variations in agronomic traits and their interactions with the environment, especially the altitude.

Table 3. Agronomic characteristics that determine the taste of coffee accessions

Accessions	Cherry Brix Content (Brix)	Cherry Water Content (%)	Water pH and Mucilage
1	12.5±0.58 ^b	33.6±1.82 ^b	5.378±0.23 ^b
2	14.04±0.26 ^{cd}	34.2±1.52 ^b	5.704±0.35 ^{bc}
3	15.8±0.45 ^e	37±0.71 ^c	4.494±0.50 ^a
4	13.88±0.26 ^c	42±2.74 ^d	4.362±0.45 ^a
5	14.56±0.36 ^d	38.5±2.09 ^c	5.714±0.17 ^{bc}
6	9.48±0.54 ^a	28.62±2.42 ^a	6.088±0.20 ^c
7	12.12±0.56 ^b	33.62±1.86 ^b	4.452±0.29 ^a
8	12.206±0.26 ^b	35.94±1.82 ^{bc}	5.934±0.13 ^c
9	18.68±0.40 ^f	42±0.71 ^d	5.376±0.24 ^b
10	19.34±0.87 ^g	38±2.55 ^c	5.374±0.15 ^b

Note: ⁿ is the highest average, ⁿ is an accession at an altitude of 1101-1300 masl, ⁿ is an accession at an altitude of 1301-1500, and ⁿ is an accession at an altitude of > 1500 masl

The agronomic characteristics that determine the taste of coffee can be seen before the coffee fruit is processed[24]. The Brix level of coffee cherries determines the quality of the coffee's taste. In addition to being an indicator of the degree of ripeness as information on harvest time, the Brix level of coffee cherries will determine the taste profile of the coffee served in a glass, especially those processed using the natural and honey methods because the pulp and mucilage are maintained during processing, which means that variations in the brix of coffee cherries (Table 3) can have a different taste effect on the results of coffee processing. In this study, the coffee accession with the highest brix was accession 10 which reached an average of 19.34 brix, this accession grew at an altitude of 1,632.34 meters above sea level. theoretically, the higher the altitude, the colder the temperature will be, so that metabolism will slow down, this causes the fruit to ripen longer, as a result the accumulation of sugar/fructose in the cherries will be higher, Accession 9 with the highest altitude should produce the highest brix, but it doesn't, which means there are limitations in plant genotype which is an important factor in regulating traits, although the environment can influence it, there are still limits to expression[25].

The content/percentage of coffee cherry water that is retained or available in the pulp and mucilage can affect the quality of coffee, because playing an important role in fermentation, post harvest processing, and the formation of flavor compounds before the coffee beans are dried and roasted. Water content also affects the density of dissolved sugar in the liquid, cherries with ideal water content will accumulate a higher density of dissolved sugar. During fermentation, microbes (bacteria and yeast) consume sugars from the mucilage/pulp and produce metabolites such as organic acids, alcohols, and enzymes that penetrate the coffee beans. These metabolites are precursors to the aroma and flavor compounds in roasted coffee beans[26]. If the water content in the mucilage/pulp is too high, fermentation can run uncontrollably, resulting in off flavors (unpleasant tastes) or spontaneous fermentation of inconsistent intensity which has a negative impact on the final taste. The pH value determines the type and activity of microbes that develop in the mucilage/pulp during fermentation. Some microbes function optimally at certain pH levels, and they produce different aroma and flavor compounds[27]. When the pH drops due to acid production, the chemical composition around the coffee bean changes, which can affect how the aroma/flavor creating compounds are formed and absorbed into the bean.

Table 4. Productivity characteristics of coffee accessions, part I

Acc	Flower/axil	Flower/fas cicle	Internode (cm)	Fruit Length (mm)	Fruith Width (mm)	Seed Length (mm)	Seed Width (mm)
1	4±1.22 ^a	9.2±2.95 ^a	5±0.61 ^{def}	17.3±0.84 ^b	14.1±0.74 ^c	16.1±0.74 ^b	11.8±1.35 ^b
2	5.8±1.64 ^{ab}	12.8±3.35 ^a	5.2±0.45 ^{ef}	17.9±0.74 ^{bc}	13.8±1.25 ^c	16.3±0.97 ^b	11.9±1.02 ^b
3	17±1.22 ^f	30.6±3.91 ^c	3.1±0.22 ^{ab}	19±1.27 ^{cd}	16.5±1.12 ^{ef}	17.7±0.84 ^c	14.8±1.30 ^c
4	5.8±1.30 ^{ab}	13.2±1.10 ^a	4.3±0.67 ^{cd}	19.3±0.84 ^{de}	15.5±1.00 ^e	18±0.61 ^c	12.7±0.67 ^b
5	10±3.81 ^{cd}	18.6±5.22 ^b	5.7±1.30 ^f	19.3±0.67 ^{de}	13.3±0.84 ^{bc}	17.8±0.45 ^c	11.8±0.45 ^b
6	14.2±1.48 ^e	26.4±3.78 ^c	2.8±0.57 ^a	15.6±0.42 ^a	11.6±0.74 ^a	13.6±0.42 ^a	9.6±0.65 ^a
7	11±2.24 ^d	20.2±3.83 ^b	3.7±0.67 ^{bc}	16.8±0.57 ^{ab}	12.6±0.42 ^{ab}	14.2±0.76 ^a	10.5±0.71 ^a
8	8±0.71 ^{bc}	18.2±2.68 ^b	2.7±0.31 ^a	17.7±1.20 ^{bc}	15.7±0.45 ^e	15.9±0.74 ^b	10.3±0.84 ^a
9	6.2±2.28 ^{ab}	13.2±2.39 ^a	4.4±0.42 ^{cde}	20.4±1.34 ^e	17.1±0.89 ^f	18.8±1.04 ^c	15.3±0.76 ^c
10	9.4±2.70 ^{cd}	18.4±5.27 ^b	3.8±0.57 ^{bc}	20.3±1.30 ^{de}	16.3±0.91 ^{ef}	18.1±1.52 ^c	15±0.71 ^c

Note: ⁿ is the highest average, ⁿ is an accession at an altitude of 1101-1300 masl, ⁿ is an accession at an altitude of 1301-1500, and ⁿ is an accession at an altitude of > 1500 masl

The number of flowers produced per axil or fascicle greatly influences the production/quantity of coffee cherries produced. The more flowers that appear, the more coffee cherries can be predicted to be produced, although it is also influenced by various factors such as weather especially rain, pollination success, wind, and other environmental conditions. The internode distance indirectly affects the quantity of coffee cherries, because flowers and cherries appear at the stem nodes, namely at the circumference where the leaves appear, so that the shorter the internode, the more stem nodes will be produced but with shorter secondary branch lengths, so that the accumulation of cherries will be greater. Primary branches that are too long and have wide internode spacing increase the potential for branch breakage when the fruit load is higher.

Coffee cherry size (length and width) and bean size (length, width, and thickness) are important agronomic traits closely related to coffee productivity and yield potential. Larger cherries generally have higher tissue capacity and photosynthate reserves, enabling them to support the development of fuller and larger beans. This results in increased bean weight per berry, yield, and yield per tree or per unit area. Meanwhile, bean dimensions (length, width, and thickness) are directly related to dry bean weight, size uniformity, and quality classification (grading), which agronomically reflect bean filling efficiency and economically relate to selling value. Variation in cherry and bean size is also frequently used as a genetic indicator in coffee selection and breeding, as these traits are relatively stable and reflect the genotype's ability to utilize the environment to produce reproductive biomass. In this study, accession 9 showed the highest averages for cherry length, cherry width, seed length, and seed width. This indicates optimal performance in this accession.

Table 5. Productivity characteristics of coffee accessions, part II

Acc	Seed Thickness (mm)	100 Cherry Weigh (gr)	100 Green Bean Weigh (gr)	Peaberry	Flower/ Primary Branch	Berry/ Primary Branch	Seed/Berry
1	5.8±0.76 ^{ab}	193.83±2.68 ^{ab}	31.55±1.04 ^d	6.4±3.13 ^{cd}	43.6±8.02 ^a	21±8.15 ^a	1.8±0.45 ^{ab}
2	6.9±0.55 ^{cd}	202.24±3.34 ^c	31.30±2.04 ^d	12.2±3.11 ^e	41±9.30 ^a	21±9.46 ^a	1.8±0.84 ^{ab}
3	7.4±0.55 ^{de}	193.39±3.03 ^{ab}	36.35±1.51 ^f	5.2±3.56 ^{bc}	124±21.66 ^c	94.2±15.61 ^{cd}	2±0.00 ^{ab}
4	7±0.35 ^{cd}	211.35±5.22 ^d	23.46±1.50 ^c	2±1.22 ^{ab}	66.6±8.62 ^{ab}	81.2±14.39 ^c	2±0.71 ^{ab}
5	9.5±0.50 ^f	198.35±4.74 ^{bc}	17.83±1.25 ^a	7±4.42 ^{cd}	62.8±12.87 ^{ab}	99.2±8.58 ^d	2.6±0.55 ^b
6	5.3±0.45 ^a	196.59±1.36 ^{ab}	24.13±0.96 ^c	16.4±5.32 ^f	247±6.44 ^e	202±17.83 ^f	1.6±0.89 ^a
7	5.5±0.71 ^a	192.80±2.50 ^a	21.34±1.48 ^b	0.8±0.84 ^a	141.6±17.62 ^c	117.6±10.09 ^e	2±0.00 ^{ab}
8	8.1±0.22 ^e	283.71±3.96 ^g	35.15±1.77 ^{ef}	21±2.74 ^g	171.6±57.43 ^d	99±16.85 ^d	2±0.00 ^{ab}
9	7.2±0.27 ^{cd}	256.53±4.62 ^f	33.66±1.32 ^e	10±2.12 ^{de}	75.6±10.45 ^b	43.6±13.90 ^b	2.4±0.55 ^{ab}
10	6.5±1.00 ^{bc}	249.74±4.82 ^e	37.05±2.24 ^f	8.4±2.61 ^{cde}	82.8±14.50 ^b	55.6±7.20 ^b	1.8±0.45 ^{ab}

Note: **n** is the highest average, **n** is an accession at an altitude of 1101-1300 masl, **n** is an accession at an altitude of 1301-1500, and **n** is an accession at an altitude of > 1500 masl

The weight of 100 coffee cherries and the weight of 100 green beans are closely related agronomic traits, because reflect the efficiency of fruit conversion into beans, which ultimately determines the productivity of the coffee harvest. In general, fresh coffee cherries contain a lot of air and pulp mass so they have a much greater weight than green beans after processing, usually around 16–20% of the weight of fresh cherries will become green beans after processing for Arabica. Variations in the weight of 100 cherries indicate differences in fruit size, density, and content (including water content), while variations in the weight of 100 green beans reflect the size, density, and physical composition of the beans, which are influenced by genetics and the environment[28]. The heavier the green bean, the larger and denser the beans, which are often correlated with higher dry bean yield potential and better physical quality in coffee bean grading standards. Accession 8 has the highest weight of 100 cherries with an average weight of 283.71 grams, while accession 10 has the highest weight of 100 green beans with an average weight of 37.05 grams.

Although it depends on the variety and environment, on average, the weight of 100 Arabica coffee cherries is 160-210 grams[29], while the weight of 100 green beans is 20.84-24.74 grams[30], Other sources state that the average weight is lower, only around 14.53-17.28 grams[31]. In this study, when compared with previous results or on red Arabica coffee, the weight of 100 cherries and 100 green beans was higher. This is important information as an introduction to further research, especially in plant breeding activities because of the potential for better fruit quantity.

Peaberry or what is usually called "lanang coffee beans" occurs when only one of the two ovules in a coffee cherry is successfully fertilized and develops, producing a single round seed inside the cherry instead of the "normal" two as can be seen in figure 3. The percentage of peaberry (generally around 5–7% of the total Arabica bean harvest) indicates variation in flower fertilization, environmental conditions, or even an imbalance in plant resources during fruit formation[32]. This variation is often influenced by genetic and environmental factors and indicates seed development errors in the coffee farm. Lanang coffee bean has a higher selling price, because it is rarer and requires a more complicated sorting process. Lanang/peaberry coffee has a higher caffeine content than regular beans, this results in a more concentrated, bitter and strong taste[33], This is caused by the accumulation of compounds that determine the taste profile and caffeine being concentrated in just one bean. In accession 8, 100 green beans were able to produce peaberries with an average of 21, the highest number in the 10 accessions studied, this makes it a potential accession that can be developed for peaberry production.



Fig. 3. Coffee bean: A. Peaberry and B. Regular bean

The number of flowers per primary branch and the number of berries per primary branch is important information to review the plant's ability to produce flowers and berries per branch. Normally, the number of flowers will be more than the number of berries formed, ranging from 56-80% for flower to fruit conversion[34], and this number depends on the presence of environmental conditions, pollinators, and genotype. In accessions 4 and 5, the number of berries formed was greater than the number of flowers identified. This was due to the asynchronous flowering, so that new flowers appeared after the count was carried out. This is caused by dynamic rainfall, because rain is an important trigger in breaking the dormancy of flower buds[35]. Unpredictable or dynamic rainfall frequency can stimulate flowering even after the first flowering stage has finished. Accession 6 is an accession with an average of 247 flowers per primary branch, but accession 7 is the accession with the largest number of berries per primary branch with an average of 117.6.

The number of beans per berry reflects the efficiency of converting the fruit into harvestable beans. In general, normal coffee cherries contain two beans[36], while singlenseeded cherries (including peaberries) produce only one bean. If the proportion of single-seeded cherries increases significantly, the total number of beans available per unit of fruit production will decrease, which can impact bean yield per cherry and overall productivity, although the trait itself is not the sole determinant of overall yield. In the research conducted, there was yellow Arabica coffee which contained 1, 2, and 3 seeds in its berry, this shows that there are 2 conditions in the form of peaberry and also regular beans with 2 and 3 seeds, one of the accessions that produced 3 seeds in 1 cherry was accession 5 with the largest average of 2.6, almost close to 3. Overall observed agronomic traits provide important information for the purpose of selecting local accessions and plant breeding. Morphological differences in accessions, apart from being a result of environmental factors, can also be caused by different provenances[37], thus opening up opportunities for further research, especially focusing on individuals/genotype with good coffee production (quantity and quality capabilities).

4. Conclusion

The study demonstrated that ten yellow Arabica coffee accessions grown in Temanggung Regency, exhibit clear variation in agronomic traits and cherry characteristics, strongly influenced by accession genotype and altitude. Higher altitudes tended to enhance key flavor related traits, particularly cherry brix content, fruit size, and green bean weight, indicating favorable conditions for producing high-quality specialty coffee. Qualitative fruit characteristics, such as ripe color and fruit disc type, proved effective for differentiating accessions and reflecting genetic diversity. Several accessions showed superior performance in productivity related traits and unique quality attributes, suggesting strong potential as candidate local superior clones. These results provide important baseline information for future coffee breeding programs and the development of yellow Arabica coffee as a high value specialty commodity adapted to specific altitude zones.

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Data and Software Availability Statements

The data in this research were obtained from direct observation and characterization in the field and laboratory. The data obtained were then analyzed and processed using Microsoft Excel 2019 and SPSS version 21 for Mac. Citation and bibliography were written using the Zotero application. The primary data for this research can be requested by the reader with the author's permission.

References

- [1] R. Mahingsapun *et al.*, "Enhancement of Arabica coffee quality with selected potential microbial starter culture under controlled fermentation in wet process," *Food Biosci.*, vol. 48, p. 101819, Aug. 2022, doi: 10.1016/j.fbio.2022.101819.
- [2] V. Poncet, P. van Asten, C. P. Millet, P. Vaast, and C. Allinne, "Which diversification trajectories make coffee farming more sustainable?," *Curr. Opin. Environ. Sustain.*, vol. 68, p. 101432, Jun. 2024, doi: 10.1016/j.cosust.2024.101432.
- [3] B. Bertrand, A. M. Villegas Hincapié, L. Marie, and J.-C. Breitler, "Breeding for the Main Agricultural Farming of Arabica Coffee," *Front. Sustain. Food Syst.*, vol. 5, Aug. 2021, doi: 10.3389/fsufs.2021.709901.
- [4] M. Geleta, I. Herrera, A. Monzón, and T. Bryngelsson, "Genetic Diversity of Arabica Coffee (*Coffea arabica* L.) in Nicaragua as Estimated by Simple Sequence Repeat Markers," *Sci. World J.*, vol. 2012, p. 939820, Jun. 2012, doi: 10.1100/2012/939820.
- [5] A. Hour, W. Hsieh, S. Chang, Y. Wu, H. Chin, and Y. Lin, "Genetic Diversity of Landraces and Improved Varieties of Rice (*Oryza sativa* L.) in Taiwan," *Rice*, vol. 13, p. 82, Dec. 2020, doi: 10.1186/s12284-020-00445-w.
- [6] "Mutations you can taste: DNA unlocks flavors of world's most popular coffee." Accessed: Jan. 29, 2026. [Online]. Available: <https://www.science.org/content/article/mutations-you-can-taste-dna-unlocks-flavors-world-s-most-popular-coffee>
- [7] B. Cheng, A. Furtado, H. E. Smyth, and R. J. Henry, "Influence of genotype and environment on coffee quality," *Trends Food Sci. Technol.*, vol. 57, pp. 20–30, Nov. 2016, doi: 10.1016/j.tifs.2016.09.003.
- [8] D. N. Rokhmah, Dani, H. Supriadi, Rusli, and N. Heryana, "Sustainable specialty coffee production: An agronomy perspective (A review)," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1230, no. 1, p. 012067, Sep. 2023, doi: 10.1088/1755-1315/1230/1/012067.
- [9] L. Romano, G. Giomo, A. Coelho, V. Filla, and L. Lemos, "Characterization of Yellow Bourbon coffee strains for the production of differentiated specialty coffees," *Bragantia*, vol. 81, May 2022, doi: 10.1590/1678-4499.20210236.
- [10] F. Luisa, F. Borém, M. Cirillo, R. Fabiana, G. Gerson, and T. Salva, "The Potential for High Quality Bourbon Coffees From Different Environments," *J. Agric. Sci.*, vol. 5, pp. 87–87, Sep. 2013, doi: 10.5539/jas.v5n10p87.
- [11] H. Ihsaniyati, N. Setyowati, and A. Phitara Sanjaya, "Farmers' attitude to standard production method based on Temanggung robusta coffee's geographical indication," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 518, no. 1, p. 012040, Sep. 2020, doi: 10.1088/1755-1315/518/1/012040.
- [12] Kompasiana.com, "Kopi Temanggung, Mengapa Jadi Kopi Terbaik di Dunia?," KOMPASIANA. Accessed: Jan. 29, 2026. [Online]. Available: <https://www.kompasiana.com/elmanurul1883/622b039bbb44866f5158f033/kopi-temanggung-mengapa-jadi-kopi-terbaik-di-dunia>
- [13] A. Hanan, A. Anhar, Y. Abubakar, and A. Karim, "Arabica coffee yields at various harvest seasons and altitudes in the Gayo Highlands, Aceh," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1297, p. 012001, Feb. 2024, doi: 10.1088/1755-1315/1297/1/012001.
- [14] B. Capili and J. K. Anastasi, "An Introduction to the Quasi-Experimental Design (Nonrandomized Design)," *Am. J. Nurs.*, vol. 124, no. 11, pp. 50–52, Nov. 2024, doi: 10.1097/01.NAJ.0001081740.74815.20.
- [15] A. Vaid, "Designing Quasi-Experimental Impact Studies of Agricultural Research at Scale".
- [16] I. P. G. R. Institute, *Descriptors for coffee (Coffea spp. and Psilanthus spp.)*. International Plant Genetic Resources Institute, 1996. Accessed: Jan. 29, 2026. [Online]. Available: <https://hdl.handle.net/10568/72788>
- [17] A. L. B. de Sousa *et al.*, "Maturation cycle and fruit-to-bean conversion ratios in amazon robusta coffee cultivars," *Rev. Caatinga*, vol. 38, p. e12571, 2025, doi: <https://doi.org/10.1590/1983-21252025v3812571rc>.

- [18] A. I. Latunra, T. D. Pasinta, M. R. Umar, and Ardiansyah, “Bantaeng Geographical Indication Arabica Coffee *Coffea Arabica*: Does Altitude Affect the Quality of the Coffee Bean?,” *J. Penelit. Pendidik. IPA*, vol. 9, no. 11, pp. 10499–10505, Nov. 2023, doi: 10.29303/jppipa.v9i11.5136.
- [19] N. Kumar *et al.*, “Impact of altitudinal variations on plant growth dynamics, nutritional composition, and free living rhizospheric N₂ fixing bacterial community of *Eruca sativa*,” *Sci. Rep.*, vol. 15, no. 1, p. 13839, Apr. 2025, doi: 10.1038/s41598-025-98242-2.
- [20] Y. Abubakar, A. Anhar, A. Baihaqi, and A. M. Mushlih, “Influence of Farm Altitude and Variety on Quality of Arabica Coffee Cherry and Bean Grown in Gayo Highland, Indonesia,” *Int. J. Des. Nat. Ecodynamics*, vol. 19, no. 3, pp. 1033–1041, Jun. 2024, doi: 10.18280/ij dne.190332.
- [21] S. Vionita, E. H. Kardhinata, and R. I. Damanik, “Morphology identification and description of coffee plants (*Coffea* sp) in Karo District,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 782, no. 4, p. 042051, Jun. 2021, doi: 10.1088/1755-1315/782/4/042051.
- [22] R. Hu, F. Xu, L. Zhao, W. Dong, X. Xiao, and X. Chen, “Comparative Evaluation of Flavor and Sensory Quality of Coffee Pulp Wines,” *Molecules*, vol. 29, no. 13, p. 3060, Jan. 2024, doi: 10.3390/molecules29133060.
- [23] S. Hoban *et al.*, “Finding the Genomic Basis of Local Adaptation: Pitfalls, Practical Solutions, and Future Directions,” *Am. Nat.*, vol. 188, no. 4, pp. 379–397, Oct. 2016, doi: 10.1086/688018.
- [24] S. Velásquez and C. Banchón, “Influence of pre-and post-harvest factors on the organoleptic and physicochemical quality of coffee: a short review,” *J. Food Sci. Technol.*, vol. 60, no. 10, pp. 2526–2538, Oct. 2023, doi: 10.1007/s13197-022-05569-z.
- [25] K. D. Subedi and B. L. Ma, “Assessment of some major yield-limiting factors on maize production in a humid temperate environment,” *Field Crops Res.*, vol. 110, no. 1, pp. 21–26, Jan. 2009, doi: 10.1016/j.fcr.2008.06.013.
- [26] F. De Bruyn *et al.*, “Exploring the Impacts of Postharvest Processing on the Microbiota and Metabolite Profiles during Green Coffee Bean Production,” *Appl. Environ. Microbiol.*, vol. 83, no. 1, pp. e02398–16, Dec. 2016, doi: 10.1128/AEM.02398-16.
- [27] E. Sholichah, D. Desnilasari, R. Subekti, M. Karim, and B. Purwono, “The influence of coffee cherry fermentation on the properties of Cascara arabica from Subang, West Java,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1011, p. 012006, Jan. 2021, doi: 10.1088/1757-899X/1011/1/012006.
- [28] M. M. Urugo, Y. B. Tola, B. T. Kebede, O. Ogah, and D. S. Mattinson, “Associations of Arabica coffee cup quality with green bean geographic origin, physicochemical properties, biochemical composition, and volatile aroma compounds,” *J. Agric. Food Res.*, vol. 18, p. 101549, Dec. 2024, doi: 10.1016/j.jafr.2024.101549.
- [29] G. Bizimungu, R. H. Ahouansou, and G. C. Semassou, “Physical and mechanical properties of Arabica coffee (*Coffea arabica* L.) cherries and beans in Rwanda,” *Food Res.*, vol. 7, no. 5, pp. 283–296, Oct. 2023, doi: 10.26656/fr.2017.7(5).498.
- [30] P. Purba, A. Sukartiko, and M. Ainuri, “Analisis Mutu Fisik dan Citarasa Kopi Indikasi Geografis Arabika Gayo Berdasarkan Ketinggian Tempat,” *J. Tanam. Ind. Dan Penyegar*, vol. 7, p. 83, Jul. 2020, doi: 10.21082/jtidp.v7n2.2020.p83-92.
- [31] M. M. Urugo, Y. B. Tola, B. T. Kebede, O. Ogah, and D. S. Mattinson, “Associations of Arabica coffee cup quality with green bean geographic origin, physicochemical properties, biochemical composition, and volatile aroma compounds,” *J. Agric. Food Res.*, vol. 18, p. 101549, Dec. 2024, doi: 10.1016/j.jafr.2024.101549.
- [32] A. Efoye and T. Kufa, “Coffee Peaberry as a Potential Seed Source for Production,” p. 30, Jan. 2020.
- [33] X. Fu *et al.*, “Comparative transcriptome analysis in peaberry and regular bean coffee to identify bean quality associated genes,” *BMC Genomic Data*, vol. 24, p. 12, Feb. 2023, doi: 10.1186/s12863-022-01098-y.
- [34] C. P. Ronchi and F. R. Miranda, “FLOWERING PERCENTAGE IN ARABICA COFFEE CROPS DEPENDS ON THE WATER DEFICIT LEVEL APPLIED DURING THE PRE-FLOWERING STAGE¹,” *Rev. Caatinga*, vol. 33, pp. 195–204, 2020, doi: <https://doi.org/10.1590/1983-21252020v33n121rc>.
- [35] M. T. Masarirambi, V. Chingwara, and V. D. Shongwe, “The effect of irrigation on synchronization of coffee (*Coffea arabica* L.) flowering and berry ripening at Chipinge, Zimbabwe,” *Phys. Chem. Earth Parts ABC*, vol. 34, no. 13, pp. 786–789, Jan. 2009, doi: 10.1016/j.pce.2009.06.013.
- [36] G. Bizimungu, “Physical and mechanical properties of Arabica coffee (*Coffea arabica* L.) cherries and beans in Rwanda,” *Food Res.*, vol. 7, pp. 283–296, Oct. 2023, doi: 10.26656/fr.2017.7(5).498.
- [37] A. H. Atmoko, T. S. Wahyudiningsih, and N. K. Kartikawati, “Analisis Keragaman Genetik Plasma Nutfah Tanaman Kayu Putih (*Melaleuca cajuputi* subsp. *cajuputi*) Berdasarkan Karakter Morfologi dan Anatomi Daun serta Oil Glands,” *J. TRITON*, vol. 14, no. 2, pp. 492–507, Dec. 2023, doi: 10.47687/jt.v14i2.699.