



# Coffee Science & Chemistry

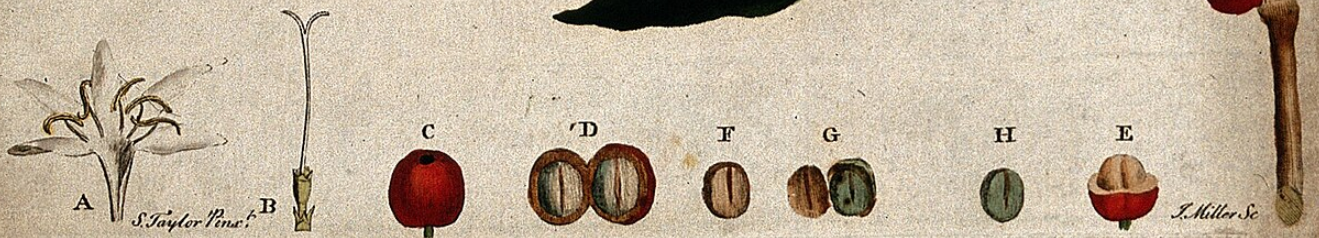
The molecular world of coffee: caffeine biosynthesis, chlorogenic acids, lipid chemistry, and what happens during roasting and extraction. A foundation reference for anyone curious about why coffee tastes the way it does. Part of The Coffee Encyclopedia, the world's largest free coffee reference, exclusively sponsored by PuertoRicoCoffeeShop.com.

- [What is Coffea Arabica? The Noble Coffee Species](#)
- [Coffee Roasting Levels: Light, Medium, Dark — and Why It Matters](#)

# **What is Coffea Arabica? The Noble Coffee Species**



COFFEA *Arabica*



Summary

*Coffea arabica* is the botanical species responsible for the majority of the world's high-quality coffee, producing beans prized for their complex flavors, pleasant acidity, and aromatic richness. Native to the highland forests of southwestern Ethiopia, arabica represents 60-70% of global coffee production and dominates the specialty coffee market entirely. Understanding arabica — its biology, cultivation requirements, and genetic characteristics — is essential to understanding why coffee from different regions tastes so different and why the species requires specific environmental conditions to produce the quality that makes coffee culture possible.

## The Botanical Basics

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<https://www.youtube.com/embed/c3NjkiDhM9k>

*Watch: Arabica vs Robusta — The Genetic Difference Explained*

*Coffea arabica* is one of approximately 130 species in the genus *Coffea*, a group of flowering plants in the Rubiaceae family (the same family as gardenia and quinine). It's a woody evergreen shrub that in its wild form grows as a small tree reaching 9-12 meters tall, though cultivated arabica is typically pruned to 2-3 meters for manageable harvesting.

Unlike most *Coffea* species, arabica is genetically unusual. It's tetraploid, meaning it carries four sets of chromosomes (44 total) rather than the two sets (22 chromosomes) found in other *Coffea* species. Scientific analysis suggests arabica originated as a natural hybrid between two other species — *Coffea canephora* (robusta) and *Coffea eugenioides* — that occurred in Ethiopia hundreds of thousands of years ago.

This tetraploid genetics makes arabica self-pollinating, meaning individual plants can reproduce without genetic input from other plants. This self-pollination creates relatively stable genetic lines but also limits the species' genetic diversity compared to cross-pollinating crops — a vulnerability that has shaped coffee industry history.

# The Coffee Cherry Life Cycle

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Understanding arabica requires understanding its reproductive cycle, which shapes everything about how coffee is farmed:

**Flowering:** Arabica trees produce delicate white flowers with jasmine-like fragrance. Flowering is typically triggered by rainfall after a dry period. A healthy arabica tree produces multiple flowering events per year under tropical conditions, though one main flowering dominates annual production.

**Pollination and fertilization:** Self-pollination occurs within hours of flower opening. The flowers last only a few days before wilting and being replaced by tiny green berries.

**Cherry development:** Green berries develop over 6-11 months, depending on variety and conditions. During this period the beans (seeds) inside the cherries develop their complex chemistry including sugars, acids, and precursors of flavor compounds.

**Ripening:** As cherries mature, they change color from green to yellow, orange, and finally deep red (some varieties ripen to yellow or pink). The color change indicates peak sugar content and optimal flavor development.

**Harvest window:** Ripe cherries must be harvested promptly. Overripe cherries develop off-flavors and attract pests. Underripe cherries lack developed flavor.

This roughly annual cycle means most arabica regions have specific harvest seasons, typically 2-4 months when workers pick cherries from hundreds or thousands of trees.



## Optimal Growing Conditions

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Arabica is botanically particular about where it will grow well. The species evolved in specific Ethiopian highland conditions and produces its best coffee only in similar environments worldwide:

**Elevation:** 600-2,200 meters above sea level. Lower elevations produce coffee too quickly, with undeveloped flavors. Higher elevations cool growing conditions, slowing development and concentrating flavors. Most premium arabica grows between 1,000-1,800 meters.

**Temperature:** 15-24°C (60-75°F) average annual temperature. Prolonged heat above 30°C damages trees. Frost kills them. The tropical highland zones that mimic Ethiopian origins suit arabica best.

**Rainfall:** 1,500-2,500 mm annually (60-100 inches), ideally distributed with a dry season that triggers flowering. Irrigation can substitute for rainfall in drier regions.

**Soil:** Deep, well-drained, slightly acidic (pH 6.0-6.5), rich in organic matter. Volcanic soils are particularly favored for their mineral content.

**Shade:** Traditionally shade-grown under larger trees, though sun-tolerant varieties exist. Shade cultivation generally produces higher-quality coffee but lower volumes.

**Rainfall patterns:** Seasonal patterns matter — coffee needs both wet periods for growth and dry periods for flowering and cherry ripening.

These specific requirements limit arabica cultivation to a geographical band called the Coffee Belt — the tropical highlands between the Tropics of Cancer and Capricorn where conditions align with arabica's needs.

## Why Arabica Dominates Specialty Coffee

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Arabica dominates the specialty coffee market because its beans develop flavor characteristics that other coffee species generally cannot match:

**Complex acidity:** Arabica beans contain multiple acid compounds — citric, malic, quinic, chlorogenic, and others — that contribute bright, clean, pleasant acidity. Well-prepared arabica can taste like lemon, stone fruit, berry, or apple.

**Aromatic richness:** Hundreds of volatile aromatic compounds develop during arabica cherry maturation and roasting. These compounds produce the characteristic coffee aroma and complex flavor layers.

**Lower caffeine:** Arabica beans contain 1.2-1.5% caffeine by weight, roughly half the caffeine in robusta. This lower caffeine reduces bitterness and allows more subtle flavors to come through.

**Sugar content:** Arabica beans contain approximately twice the sugar of robusta, providing sweetness and complex Maillard reactions during roasting that develop caramel and chocolate notes.

**Lipid content:** Higher lipid content in arabica contributes to body and mouthfeel in the brewed cup.

The combination produces coffee that can taste like an extraordinary range of things — from jasmine and bergamot to chocolate and almond to cherry and stone fruit — depending on variety, terroir, and preparation.



# Arabica's Vulnerabilities

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Arabica's specialized nature comes with significant vulnerabilities:

**Disease susceptibility:** Arabica is particularly vulnerable to coffee leaf rust (*Hemileia vastatrix*), coffee berry disease, and several other fungal pathogens. Major rust outbreaks have devastated arabica regions repeatedly throughout coffee history.

**Pest susceptibility:** The coffee berry borer and various leaf miners specifically attack arabica more heavily than other *Coffea* species.

**Climate sensitivity:** Arabica's narrow temperature and rainfall requirements make it highly vulnerable to climate change. Warming trends are pushing viable arabica growing zones higher up mountainsides and threatening traditional coffee regions.

**Genetic bottleneck:** Most commercial arabica varieties trace back to a small number of plants transported from Ethiopia centuries ago, creating limited genetic diversity that undermines disease resistance.

**Lower yield:** Arabica trees produce less coffee per tree than robusta, requiring more land and labor to produce equivalent volumes.

These vulnerabilities shape the modern coffee industry's challenges. Climate change, disease pressure, and labor economics all threaten arabica cultivation in ways that researchers and farmers work continuously to address.



## Commercial Varieties

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Within the *Coffea arabica* species, agricultural breeding and natural selection have produced dozens of distinct varieties. Major varietal lineages include:

**Typica:** The oldest cultivated arabica variety, descended from original Yemen-Ethiopia stock. Most Caribbean coffee including Puerto Rican Typica traces to this lineage.

**Bourbon:** A natural mutation of Typica that arose on the island of Bourbon (modern Réunion). Bourbon spread globally and produced many secondary varieties.

**Caturra:** A natural dwarf mutation of Bourbon discovered in Brazil, allowing denser planting and easier harvesting.

**Catuaí:** A Bourbon-Caturra hybrid developed in Brazil.

**Gesha (Geisha):** Originally from Ethiopia via Panama, famous for exceptionally floral and complex flavors that command premium prices.

**SL28 and SL34:** Classic Kenyan varieties producing distinctive bright, fruity coffees.

**Pacas, Pacamara, Villa Sarchí:** Various Central American varieties with specific regional characteristics.

**Modern hybrids:** Including Limaní (developed for Puerto Rican conditions), Obatã, Timor hybrid derivatives, and others bred for disease resistance.

Each variety offers different combinations of yield, disease resistance, altitude tolerance, and cup quality. Farmers choose varieties based on their specific conditions and market objectives.

## Arabica's Global Production

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Arabica accounts for approximately 60-70% of global coffee production annually, with the remaining 30-40% primarily composed of *Coffea canephora* (robusta). The major arabica producing countries include:

**Brazil:** World's largest arabica producer, with vast plantations especially in Minas Gerais state.

**Colombia:** Famous for consistent, high-quality washed arabica from Andean mountain regions.

**Ethiopia:** Arabica's birthplace, producing exceptional heirloom varieties from traditional farming systems.

**Central America:** Guatemala, Honduras, Costa Rica, Nicaragua, and El Salvador all produce significant arabica volumes with distinctive regional characteristics.

**Kenya and Ethiopia:** East African arabica is widely considered among the world's finest.

**Puerto Rico:** A small but historically significant arabica producer with strong regional identity.

**Other regions:** Mexico, Peru, Vietnam's highlands, Indonesia, and smaller producers globally all contribute to arabica supply.

## Arabica in Your Cup

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Every specialty coffee experience depends on arabica's biology. The mountain terroir that shapes regional flavor differences only matters because arabica is capable of expressing terroir — responding to soil, climate, and farming practices with variable flavor development. Cheaper robusta, by contrast, tends toward more uniform flavor regardless of origin.

When you taste chocolate notes in Yauco coffee, floral hints in Yirgacheffe, citrus brightness in Kenyan AA, or caramel sweetness in Colombian supremo — you're tasting arabica genetics responding to specific growing conditions. The species provides the palette; terroir, variety, and preparation provide the painting.

## Key Facts

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- **Scientific name:** *Coffea arabica*
- **Chromosome count:** 44 (tetraploid)
- **Caffeine content:** 1.2-1.5% by bean weight
- **Sugar content:** Approximately twice robusta
- **Origin:** Highland forests of southwestern Ethiopia
- **Global production share:** 60-70% of all coffee
- **Optimal elevation:** 600-2,200 meters (premium 1,000-1,800m)

- **Optimal temperature:** 15-24°C annual average
- **Self-pollinating:** Yes
- **Main disease threat:** Coffee leaf rust (*Hemileia vastatrix*)

## Frequently Asked Questions

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**Q: What is the difference between arabica and regular coffee?** "Regular coffee" usually refers to arabica, which makes up most of the coffee sold globally. The main alternative species is robusta (*Coffea canephora*), which is stronger-tasting, higher in caffeine, and generally considered lower quality than arabica for specialty markets.

**Q: Why is arabica considered better quality than robusta?** Arabica contains more complex flavor compounds, has lower bitterness, features more pleasant acidity, and contains about half the caffeine of robusta. These characteristics make arabica more suitable for specialty coffee preparations where flavor nuance matters.

**Q: Does all good coffee come from arabica?** Most specialty coffee is arabica, though some quality-focused robusta and hybrid varieties exist in specialty markets. Traditional espresso blends often include robusta for body and crema, even in specialty preparations.

**Q: Can I grow arabica coffee at home?** Arabica can grow as an indoor houseplant in temperate climates, producing attractive foliage and occasional small crops of cherries. However, commercial-quality coffee requires specific highland tropical conditions difficult to replicate indoors.

**Q: What does arabica coffee taste like?** Arabica offers enormous flavor variety depending on variety and terroir — ranging from floral and tea-like (Ethiopian) to chocolate and caramel (Brazilian, Puerto Rican) to bright and fruity (Kenyan, Colombian) to clean and balanced (Central American).

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**Related Articles:** Ethiopia: The Birthplace of Coffee | The Typica Coffee Variety | The Bourbon Coffee Variety | What is Coffea Canephora (Robusta)?

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# Coffee Roasting Levels: Light, Medium, Dark — and Why It Matters

# Coffee Roasting Levels: Light, Medium, Dark — and Why It Matters

| Comparison         |                  |                 |
|--------------------|------------------|-----------------|
| Option A           |                  | Option B        |
|                    | ORIGIN           |                 |
| Ethiopia           |                  | Yemen           |
|                    | FIRST CULTIVATED |                 |
| Wild forests, 9c.  |                  | Terraces, 15c.  |
|                    | PROCESSING       |                 |
| Natural + washed   |                  | Natural only    |
|                    | FLAVOR           |                 |
| Floral, tea-like   |                  | Deep, winey     |
|                    | KEY VARIETY      |                 |
| Heirloom landraces |                  | Udaini, Dawairi |

— PuertoRicoCoffeeShop.com

Roast level is one of the three biggest variables that determine how coffee tastes — alongside origin and brewing method. Roasting transforms raw green coffee beans through carefully controlled heat, breaking down the bean's structure, caramelizing sugars, generating new aromatic compounds. The longer and hotter the roast continues, the darker the bean becomes. Light roasts preserve the original character of the bean — the terroir, the variety, the elevation — but at the cost of higher acidity and less developed sweetness. Dark roasts produce richer, fuller-bodied cups but obscure origin character behind roast-derived flavors. Medium roasts balance the extremes, which is why most American specialty

coffee falls in the medium range. Understanding how roast level affects flavor unlocks the ability to choose coffees deliberately for the cup character you want.

## What Roasting Actually Does

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Roasting transforms green coffee beans through heat. A green bean is hard, pale grayish-green, dense, almost flavorless. The same bean after roasting is brown, less dense, brittle, and full of complex flavor compounds.

The drying phase (0-200°C) releases water vapor. Internal water content drops from 11-12 percent to under 5 percent. The bean color shifts from grayish-green through yellow to light tan.

The Maillard reaction phase (140-160°C onward) begins as reducing sugars react with amino acids to produce hundreds of new aromatic compounds. This is the same reaction that browns bread crust and sears steak. Maillard browning produces deep nutty, malted, and bready notes.

The caramelization phase (170°C+) produces sweetness and dozens more flavor compounds.

First crack at approximately 196°C marks the transition from underdeveloped to drinkable. The bean's internal water reaches a critical pressure point and the bean physically pops, producing an audible cracking sound. After first crack, the bean is in the light roast zone.

The development phase between first and second crack is where most specialty coffee finishes. Stopping just after first crack produces light roasts; continuing further produces medium roasts.

Second crack at approximately 224°C is a second physical fracturing of the bean cellular structure. The sound is quicker and sharper, like Rice Krispies in milk. At second crack, the bean enters dark roast territory. Oils begin migrating from the bean's interior to its surface.

After second crack, continuing to roast pushes through Full City+, Vienna, French, and Italian roast levels. Beyond that, the bean is essentially charred and produces ashy, burnt flavors.

## **Light Roast: Preserving Origin Character**

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Light roast is roasted to first crack or just slightly past — approximately 200-205°C. Beans are pale brown, dry-surfaced. Traditional names: Cinnamon roast, City roast (the lightest commonly drinkable level), American roast.

Cup character: bright pronounced acidity; floral, fruity, citrus, tea-like notes; origin character at maximum visibility; lighter body; restrained sweetness.

Light roasts work best with single-origin coffees from origins prized for character (Ethiopian, Kenyan, Panama Geisha). Filter brewing methods favor light roasts because the longer extraction allows full flavor development.

Specialty coffee culture has been dominated by light roasts since the early 2000s.

## **Medium Roast: The Balanced Center**

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Medium roast falls between first and second crack — approximately 210-220°C. Beans are medium brown. Traditional names: City+, Full City, Breakfast, American medium.

Cup character: balanced acidity, moderate body, pronounced sweetness, balance between origin-derived and roast-derived flavors. Caramelization sugars peak in this zone, producing chocolate, caramel, nut, and brown sugar notes.

Medium roasts deliver the cup character most American consumers prefer. The vast majority of specialty coffee sold in the US falls in the medium range.

## **Dark Roast: Roast-Forward Character**

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Dark roast is taken into or past second crack — approximately 225-235°C. Beans are dark brown to nearly black, with visible oil sheen. Traditional names: Full City+, Vienna, French, Italian.

Cup character: low acidity, heavy body, pronounced bitterness, smoky and roasted flavors, reduced origin character.

Dark roasts work for traditional Italian-style espresso, milk-based drinks, French press, and people who prefer low-acid coffee.

Specialty coffee culture has largely moved away from dark roasts because they obscure origin character. James Hoffmann and others have pushed back — properly executed

dark roasts can produce excellent cups.

## How Roast Level Affects Each Variable

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### The Coffee Encyclopedia



*roast level effect chart*

Image curation pending

= PuertoRicoCoffeeShop.com

Acidity decreases as roast progresses. Body increases slightly to medium, then stays roughly constant. Sweetness peaks in medium roast. Bitterness increases steadily. Origin character decreases steadily. Roasted flavors increase steadily. Caffeine content stays roughly constant.

## The Caffeine Myth: Light vs Dark

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## Comparison

### Option A

Ethiopia

Wild forests, 9c.

Natural + washed

Floral, tea-like

Heirloom landraces

ORIGIN

FIRST CULTIVATED

PROCESSING

FLAVOR

KEY VARIETY

### Option B

Yemen

Terraces, 15c.

Natural only

Deep, winey

Udairi, Dawairi

— PuertoRicoCoffeeShop.com

Per bean, caffeine content is roughly constant across roast levels. Caffeine is heat-stable and doesn't degrade significantly during normal roasting.

Per gram, dark roasted beans weigh less per bean (more water has evaporated), so dark roasts have slightly more caffeine per gram.

Per scoop, dark roasted beans are also less dense, so light roasts can have slightly more caffeine per scoop.

Per brewed cup, brew strength matters more than roast level. The roast-level effect on caffeine is small enough to be irrelevant for most drinkers.

## Matching Roast to Brewing Method

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# The Coffee Encyclopedia



*brewing methods roast level pairing*

Image curation pending

— PuertoRicoCoffeeShop.com

Espresso traditionally pairs with medium-dark to dark roasts. Modern specialty espresso has shifted lighter, with many medium-roast espressos.

Pour-over and drip pair well with light to medium roasts. The longer extraction develops the complex flavors light roasts contain.

French press and immersion pair well with medium to medium-dark roasts.

AeroPress is exceptionally versatile — works well with everything.

Cold brew traditionally uses medium to dark roasts.

## Puerto Rican Coffee Roast Levels

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# The Coffee Encyclopedia



*puerto rican coffee roast preferred levels*

Image curation pending

— PuertoRicoCoffeeShop.com

The high-altitude beans from Yauco, Adjuntas, Lares, Jayuya, and Maricao tend to be dense, clean, and well-developed. Traditional Puerto Rican roasting was roughly medium to medium-dark — Full City to Full City+. This emphasized balanced sweetness, rounded body, and the chocolate-and-stone-fruit character that Puerto Rican beans deliver beautifully.

The dense bean structure rewards careful development. Under-roasted Puerto Rican coffees can taste sour or grassy. Properly developed at City+ to Full City, the beans deliver their full character.

## Common Misunderstandings

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Darker is stronger is false. Light roasts have more caffeine is roughly false. Dark roasts are bad is a specialty preference, not universal. All medium roasts are the same is false. Espresso must be dark is outdated.

## Key Facts

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- First crack occurs at approximately 196°C
- Second crack occurs at approximately 224°C
- Light roasts preserve origin character but have higher acidity
- Medium roasts balance origin and roast-derived flavors with peak sweetness
- Dark roasts emphasize roast flavors and reduce origin character
- Acidity decreases as roast darkens; bitterness increases
- Caffeine content is roughly constant across roast levels
- Puerto Rican coffees traditionally roast medium to medium-dark

<https://www.youtube.com/embed/lrRdRxAqMHc>

## Frequently Asked Questions

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### **Which roast level is best?**

There is no universal best. The best roast depends on what you want to taste.

### **Why does my light roast taste sour?**

Either the roast is underdeveloped or the brewing is under-extracted. Try roasting slightly darker, or brewing with finer grind, longer time, or hotter water.

### **What's the difference between Full City and French roast?**

Full City is right at the brink of second crack — medium-dark territory. French is fully through second crack — dark roast with fully oily beans.

### **Why is most American coffee darker than European specialty?**

Cultural preference and historical trajectory. American mass-market coffee was built on dark roasts. Specialty Europe embraced lighter roasts to showcase origin character.

### **Can I roast coffee at home?**

Yes, with appropriate equipment. Home roasting requires learning to read first and second crack and developing taste calibration.

## **Related Articles**

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- [Coffee Processing: Washed, Natural, and Honey Methods Explained](#)
- [About Coffee Extraction Mathematics](#)
- [Modern Experimental Coffee Processing: Anaerobic, Carbonic Maceration, and Beyond](#)
- [Coffee Cupping: The SCA Protocol and How Professionals Taste Coffee](#)
- [The Coffee Flavor Wheel: How Professionals Describe Coffee Taste](#)
- [Yauco: Puerto Rico's Crown Coffee Region](#)

## **Taste Authentic Puerto Rico Coffee**

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The high-altitude single-origin beans from Yauco, Adjuntas, Lares, Jayuya, and Maricao are roasted to balance natural chocolate-and-stone-fruit character with the medium-dark

traditional Puerto Rican identity. [PuertoRicoCoffeeShop.com](http://PuertoRicoCoffeeShop.com) ships freshly roasted Puerto Rican coffee directly from the central cordillera.

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