



Partageons les savoirs

Breeding new coffee varieties to improve the sustainability of coffee in the face of climate change.

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ASIC Secretary

1. Overview and challenges of Canephora breeding
2. Overview and Challenges of Arabica breeding
3. Probabilities for delivering new varieties well-adapted to Global warming and future farming systems

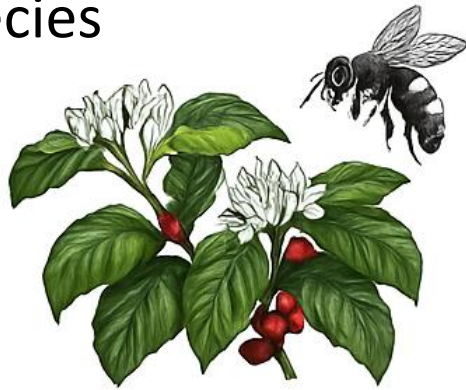
2. Overview and challenges of *C. canephora* breeding



Diversity of shape and colour of coffee berries observed the same day in a *C. canephora* population Photo B. Bertrand

Reproduction system of *Coffea canephora*

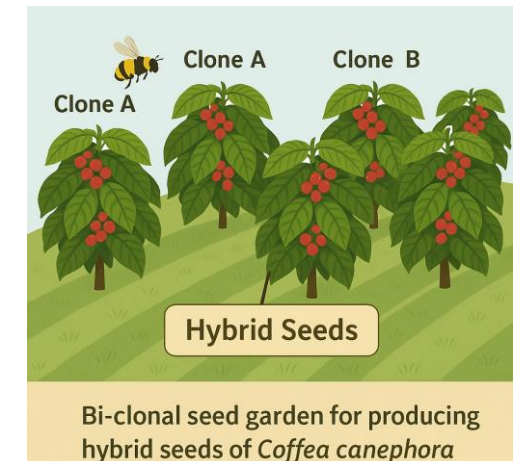
Allogamous
species



Vegetative propagation

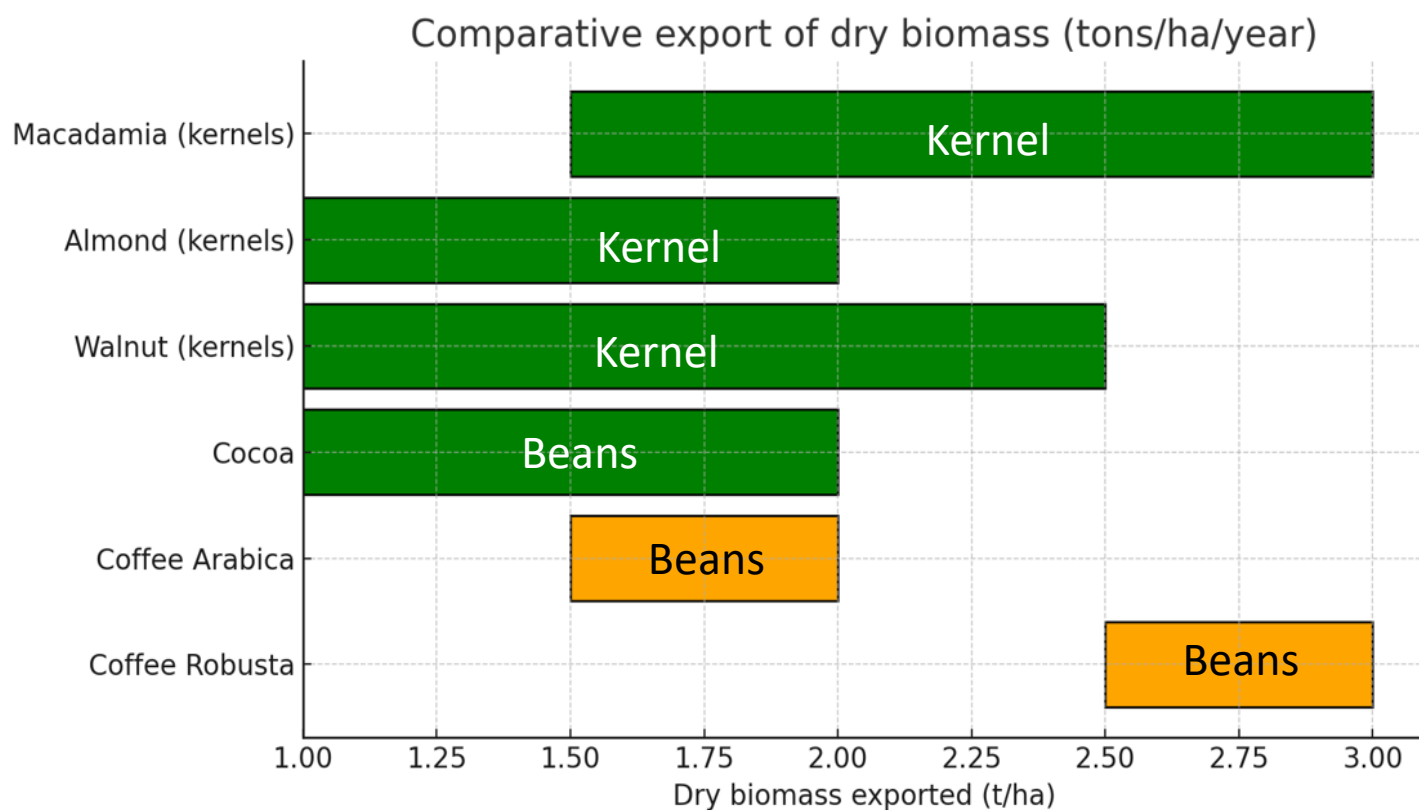


Seed propagation



1st major discovery: the selection of the species

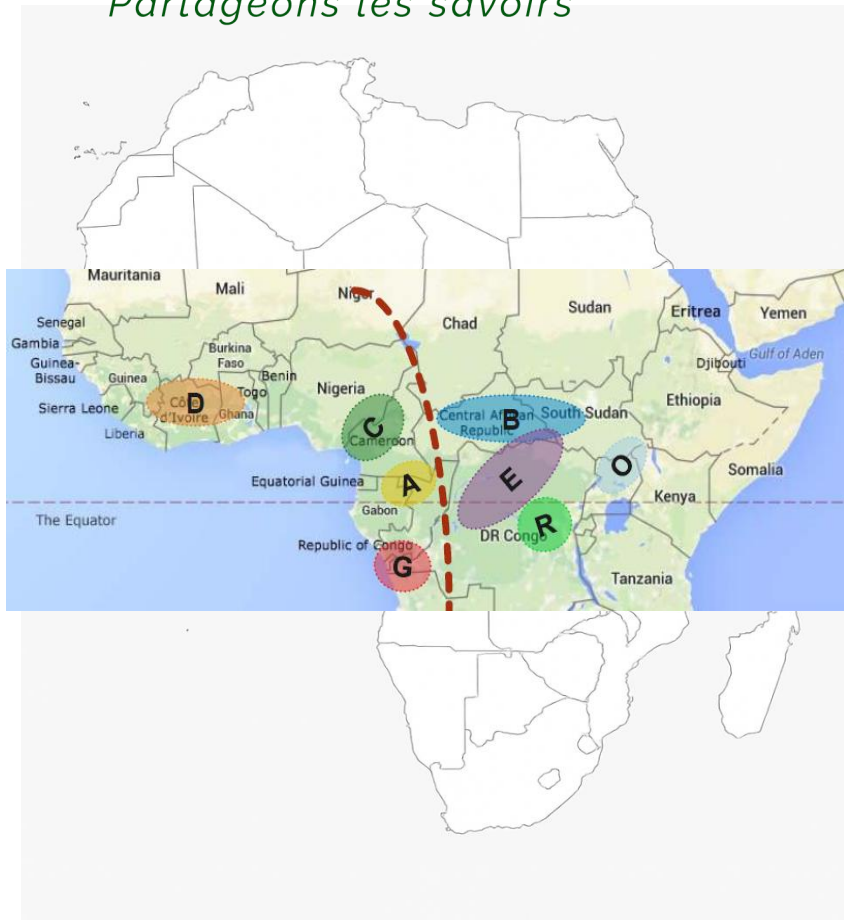
In 1900 **Linden** launched a robust, pest-resistant, and productive coffee species under the name “*Coffea robusta*” (Verleysen et al., 2023)



From a wild species discovered in the 19th century, a very productive crop was created.

2nd discovery: genetic ~ geographical groups

Partageons les savoirs



Berthou et al.1980, Berthaud et al., 1986	Montagnon , Leroy, Yapo (1992; 1993)	Dussert et al., 1999	Musoli et al.;2009 Cubry et al., 2013	Gomes et al., 2009; Merot-l'Anthoene et al., 2019	Geographical origin
Guinean	Guinean	D	Guinean	D	Guinea and Ivory Coast
Congolense	SG1	A	SG1	A	Atlantic side of Central Africa (Gabon and Congo and western DRC)
	SG2	E	SG2	E	Congo River Basin (DRC)
		B	B	B	Eastern Central African Republic
		C	C	C	Cameroon, western Central Africa region
				R	Southern DRC
			O	O	Uganda
				G	Angola

Strong differentiation among cluster from EastAfrica(OBER) and cluster from West Africa (ACGD)

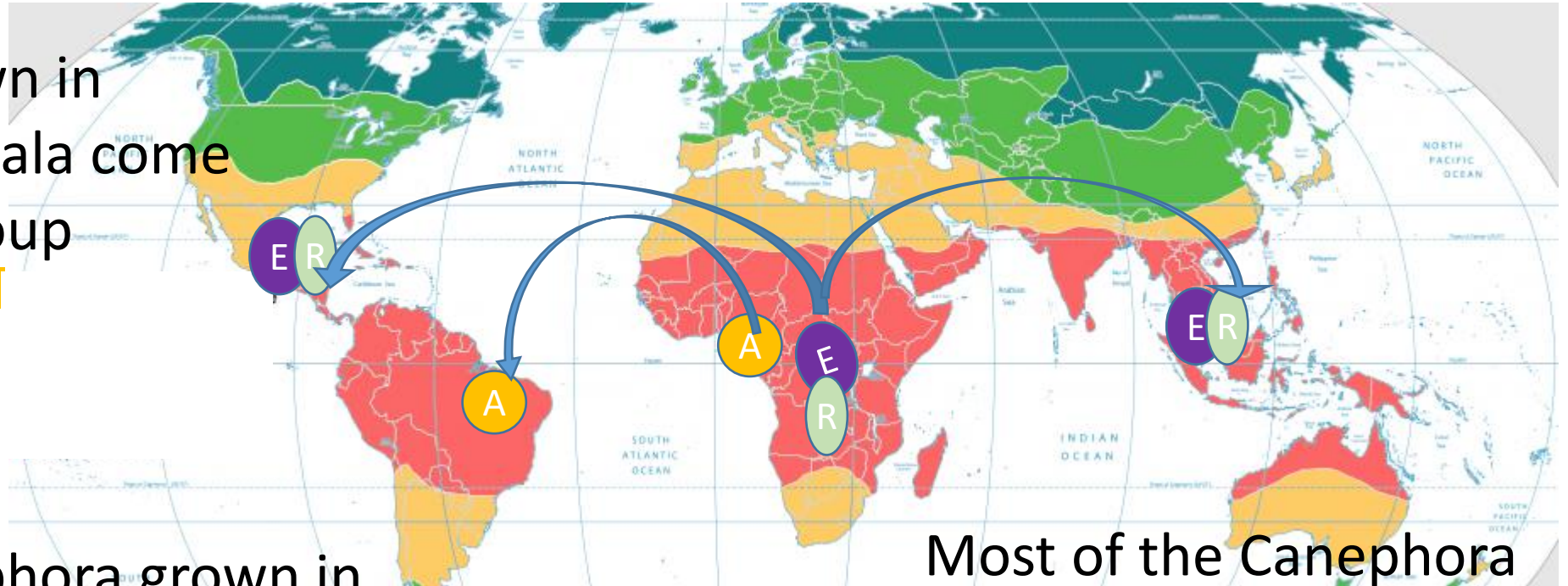
Which group do the varieties outside Africa belong to?

Canephora grown in Mexico/Guatemala come from the E-R group

Garavito, Guyot, Montagnon, Bertrand 2016

Canephora grown in Brazil come from the A group (conilons)

Cubry et al. (2008)



Most of the Canephora grown in Asia come from the E-R group

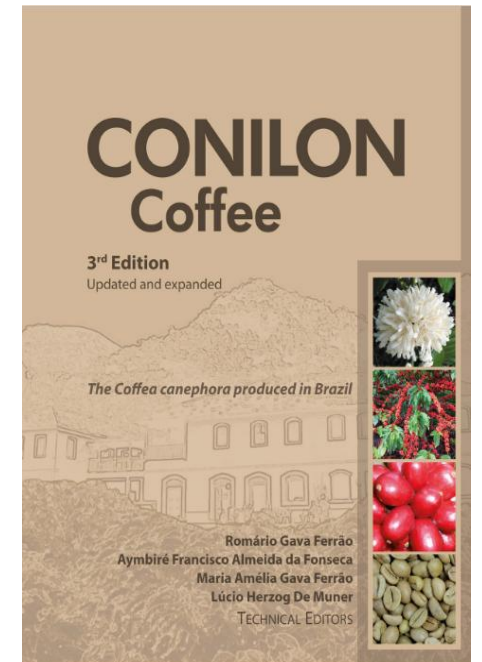
Garavito, Guyot, Montagnon, Bertrand 2016
Pangestika et al., 2021
Vi et al., ..Poncet , 2023

Outside Africa, even with narrow genetic base substantial genetic progress has been made



In Vietnam, high-yielding clons (E-R group) (cvs e TR4, TR9, TRS1 and TS5, TRS1 (Chung et al., 2021)

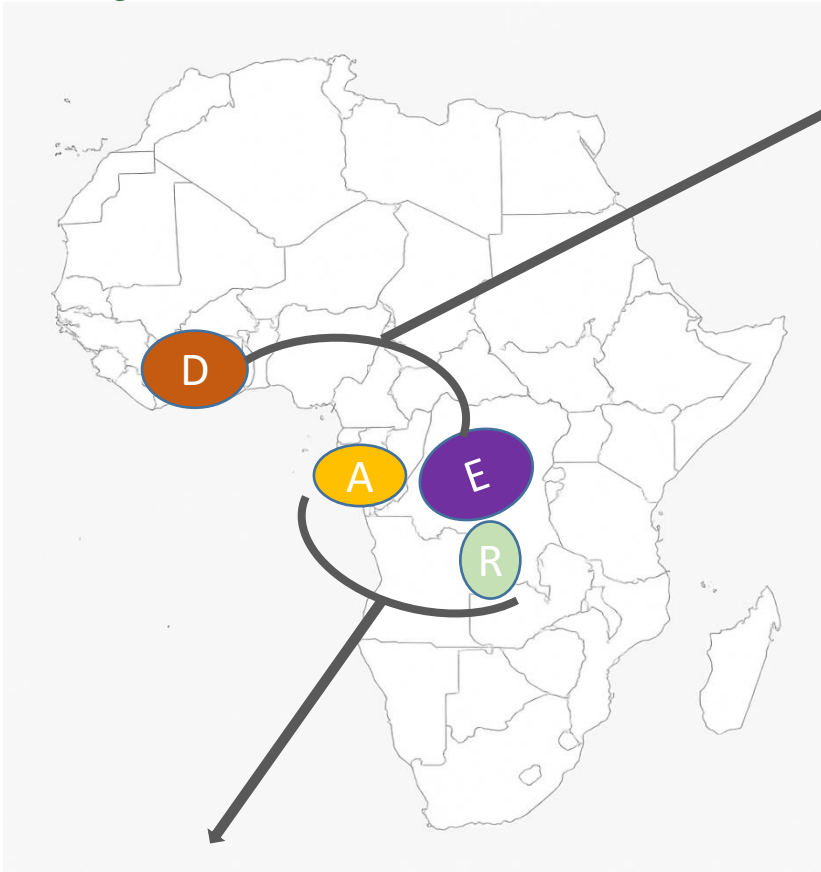
In Brazil: more than 40 clonal cultivars. The conilon' 'Emcaper 8151' is produced by seeds.



3rd discovery: Hybrids intergroups allowed heterosis and complementarity

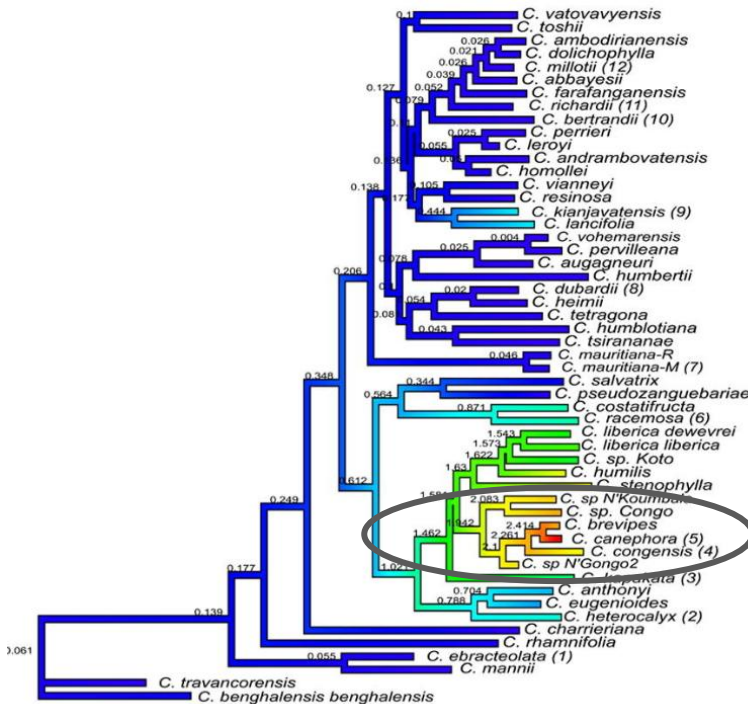
Intergroup Guinean (D) x Congolense (E-R)
hybrids can exceed the level of the parental
clones by up to 40% in terms of yield and vigor
(Montagnon, Yapo, Leroy et al., 2003).

Complementarity between groups

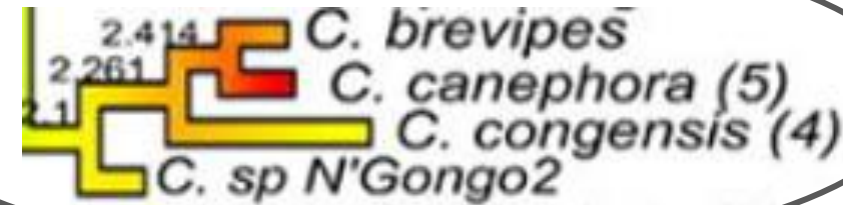


Intergroup Conilon (A-G) x Congolense (E-R) best
hybrids produced 22 to 60% more than the
average populations of hybrids (Carvalho et al.,
2019; Rocha et al.; 2021)

4th discovery: we can use the The Canephora alliance in breeding programs



Canephora
Alliance



Crossbreeding
results in fertile hybrids

(Louarn, 1992)



Integrating wild relatives to increase the
diversity

Phylogenetic tree of coffee species

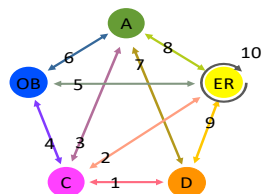
Hamon et al., 2017

Partageons les savoirs

Step 1:
Crosses between the best
performers of each genetic
groups

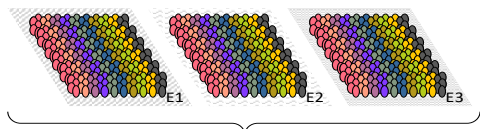
*Option 1: Wild relatives
species can be used in a
second round of crosses*

*Option 2: Use pangenomes
to select genitor*



1-2 years

Step 2:
Comparison of
populations in 3
contrasting environments
cropping systems

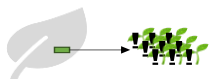


5-6 years

Step 3:
Cross selection based on
high yielding

Selection of 30 clones precandidate by environment (E)
*Develop multi-traits and multi-environments. Genomic/Phenomic
selection can halve the time*

Step 4:
Cloning of the best pre-
candidate clones (3x30)
somatic
embryogenesis



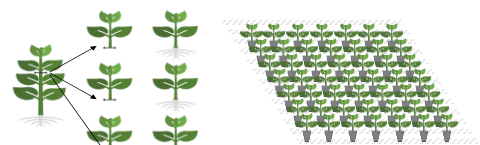
1-2 years

Step 5:
Test the best pre-
candidate clones in
several field conditions
(representing various
cropping systems and
environments)



5-6 years

Step 6:
Clone propagation by
vegetative reproduction in
commercial nurseries
(cutting)

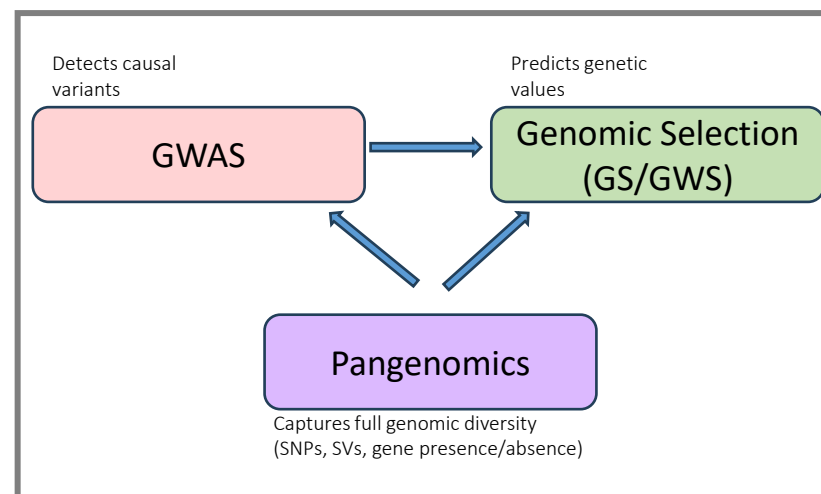


2 years

Figure 1:
Crosses between the best
performers of each genetic
group (step 1), and the
best clones (step 2), are
available to broaden the genetic base and/or reduce selection time.

Inter-groups hybrids assisted by Genomic selection

+



=

Hybrid clones

3. Overview and Challenges of Arabica breeding



Compact habit

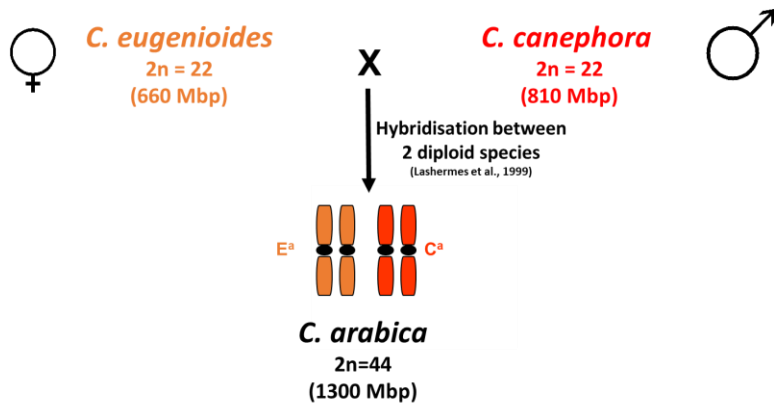


Open habit



Reproduction system of *Coffea arabica*

Arabica an allotetraploid species



Autogamous species
(85-90%)



Predominantly
propagated by seeds



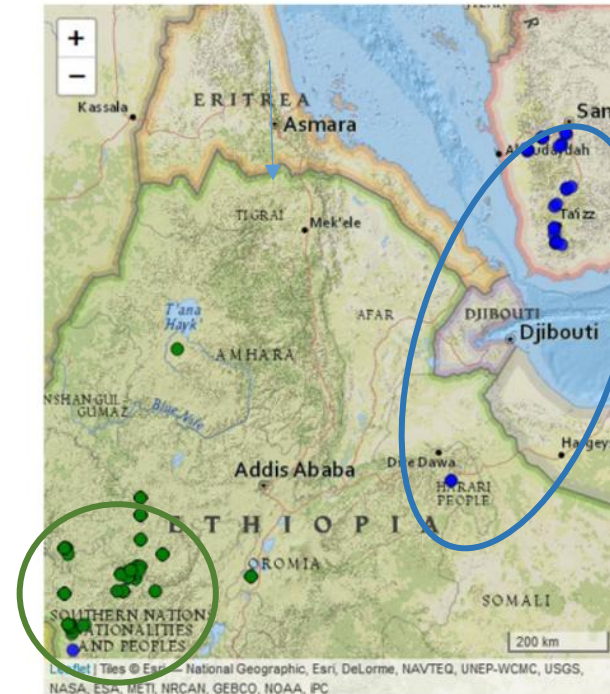
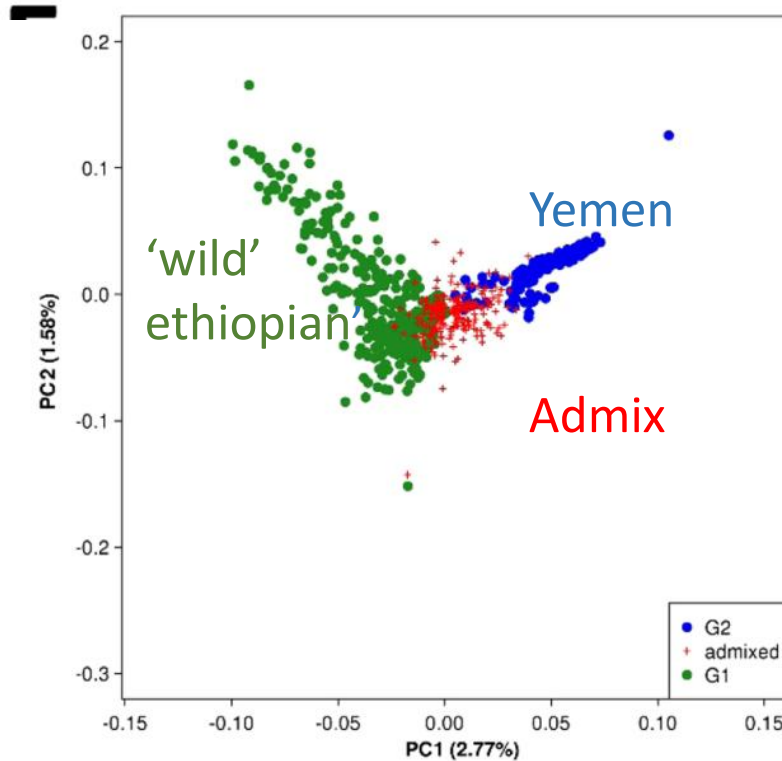
The Arabica species is a survivor

- A single allopolyploidisation event gave rise to *C. arabica* following the hybridisation event (Lashermes et al., 2016)
- There were severe bottlenecks (Salojärvi et al., 2024)
- The species nearly became extinct 10-15 kya ago (Scalabrin et al., 2020)

Genetic diversity of Arabica

Only two main polymorphics groups

(Anthony et al., 2002; Scalabrin et al. 2020)

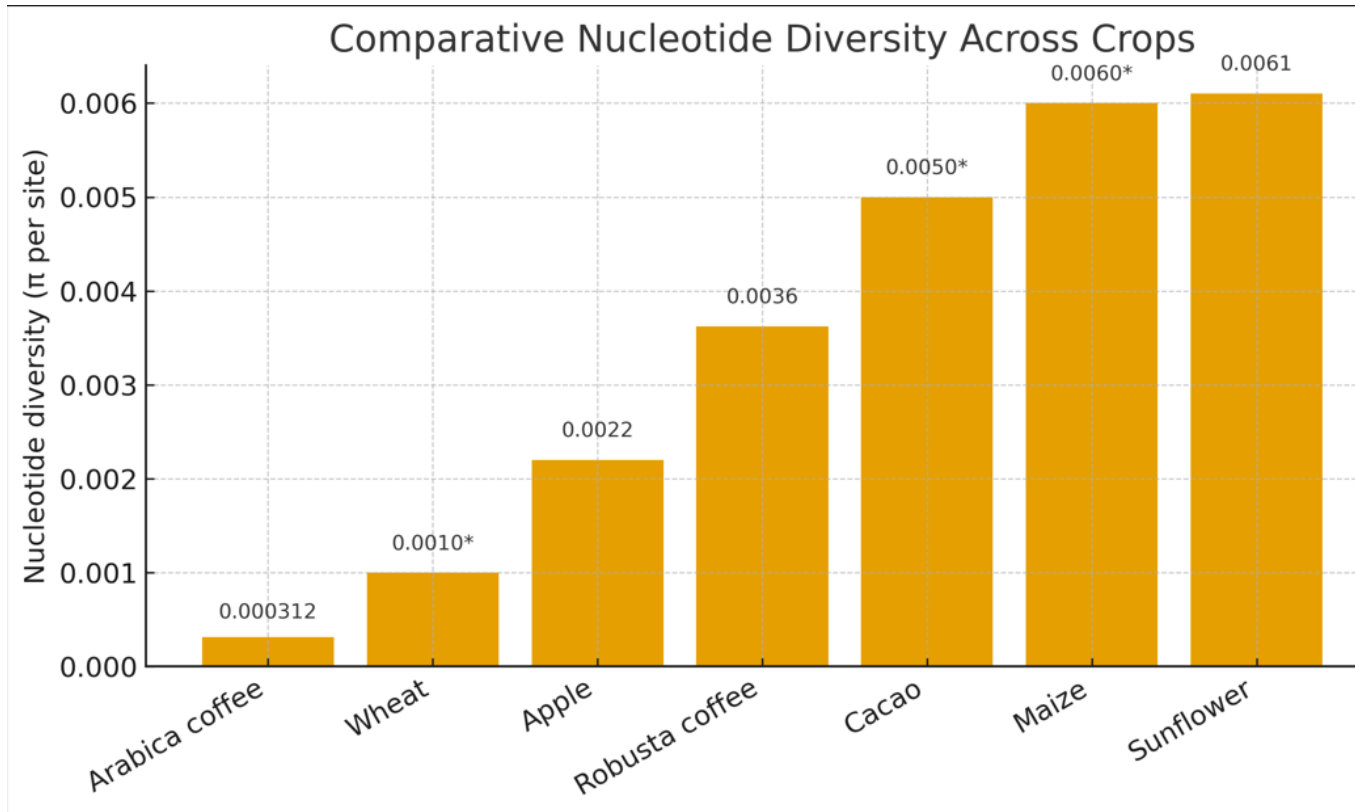


Yemen (Harare)
with 2 sub-groups
Montagnon et al; 2022

'Wild' Ethiopian south west Ethiopia
with 2 subgroups : 'Sheka' in wild forest and 'Jimma Bonga' cultivated in garden

Klein... Bertrand, 2016; Scalabrin ...Bertrand, 2020

Very low nucleotide diversity at the genome level

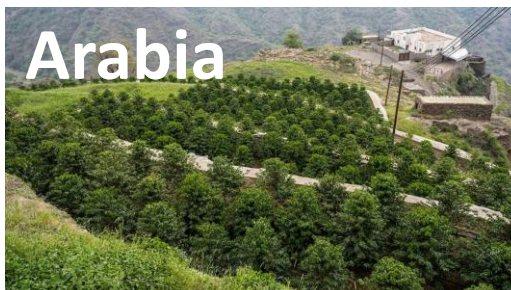


The genetic diversity of Arabica, is:

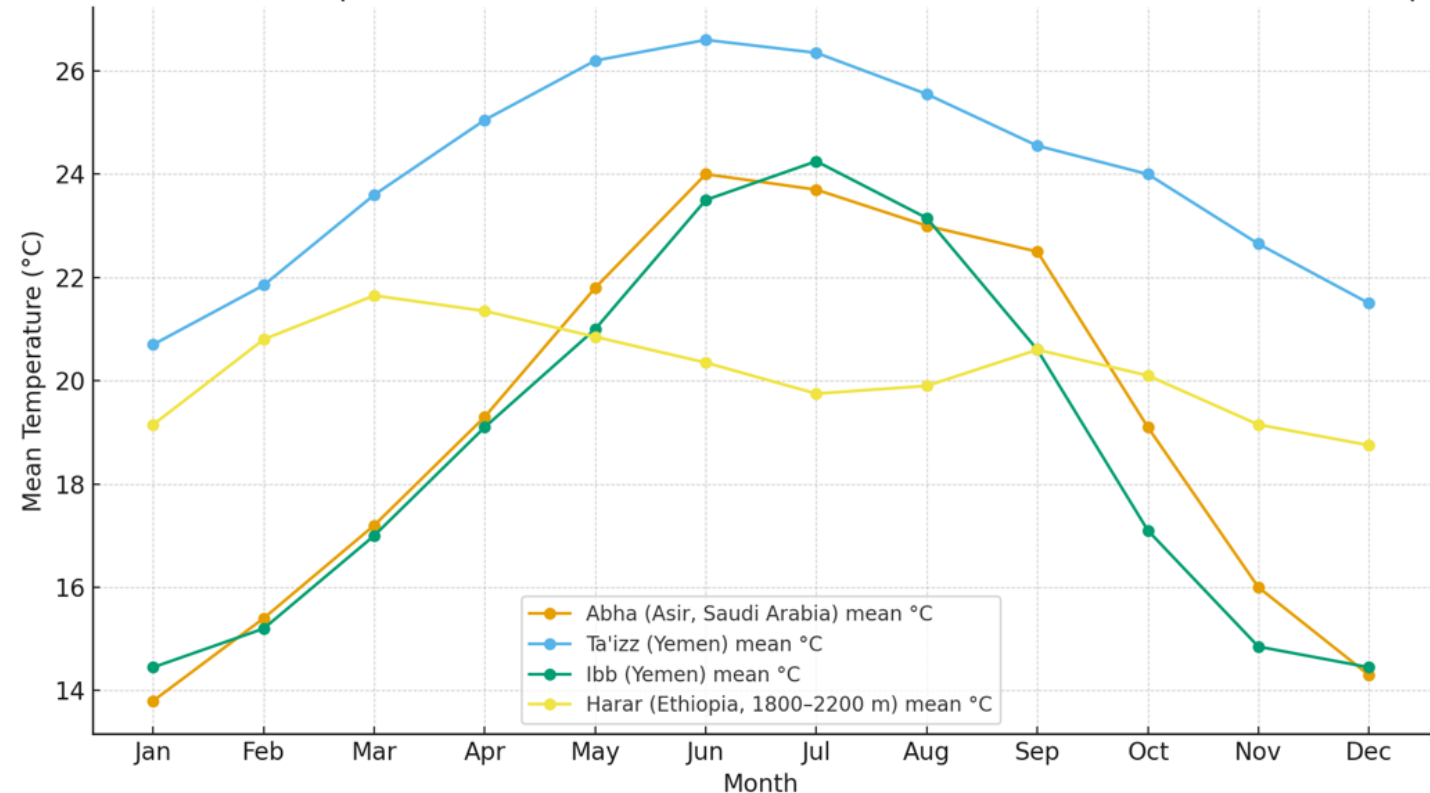
- 12 times less than that of *C. canephora*
- 20 times less than that of corn

1st 'breeding program' in Ethiopia and Yemen

From Ethiopian forest to full-sun with low or warm temperatures cultivation in Saudi Arabia/ Yemen/Harar



Annual Mean Temperature Curves - Main Coffee Areas (Saudi Arabia, Yemen & Ethiopia)



2nd Breeding program Brazil: Pedigree selection

1950-1980

Major discovery:

1. Complementarity Typica/Bourbon
2. Discovery of dwarfism
3. Breeding for adaptation to intensive farming system: green revolution based on dwarfism (cultivar Catuai) or mechanization (cultivar Mundo Novo)

3rd Breeding program Timor-hybrid derived pure line varieties

- The resistant Hibrido Timor hybrid was discovered in a C. arabica field on the Timor island (1917)
- Several countries have cooperated with Coffee Rust Research Center (CIFC), Oeiras-Portugal for the development of local adapted coffee cultivars displaying rust resistance through the Timor Hybrid

4th breeding program: F1 hybrids

- **F₁ hybrid creation**, which has revolutionized varietal development in many crops, is only possible when three key conditions are met:
 - **Strong heterosis** (existence of heterotic groups)
 - **Feasible seed production** at an affordable cost
 - **Market demand** for uniform hybrid varieties
- It took **over 40 years of research** to bring all these conditions together in *Arabica coffee*.

F1 hybrid of Arabica have been developed by crossing two heterotic groups

Yield dwarfsim

Dwarf American varieties



Tall Southwestern Ethiopian



Ethiopia:
Diversity
reservoir



Cup quality

X



F1 hybrids

Centroamerica

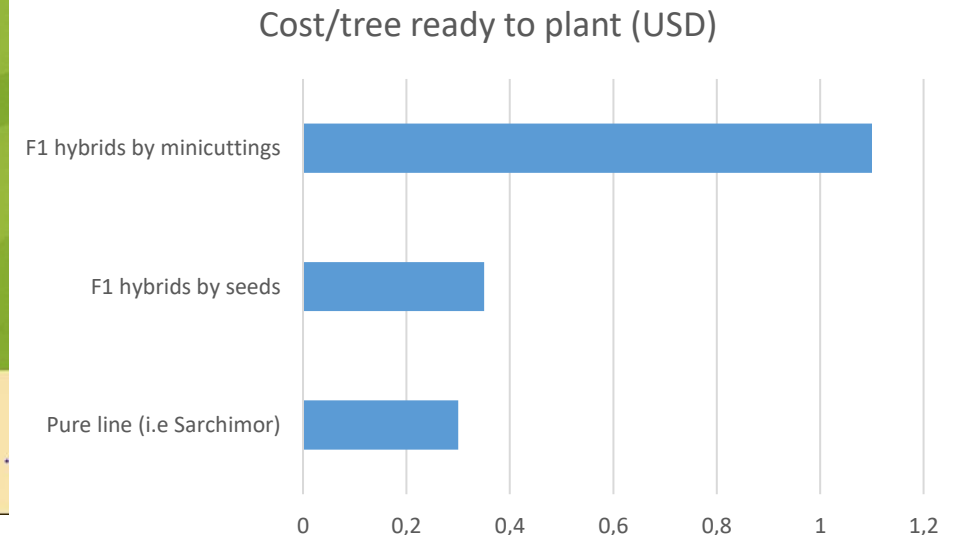
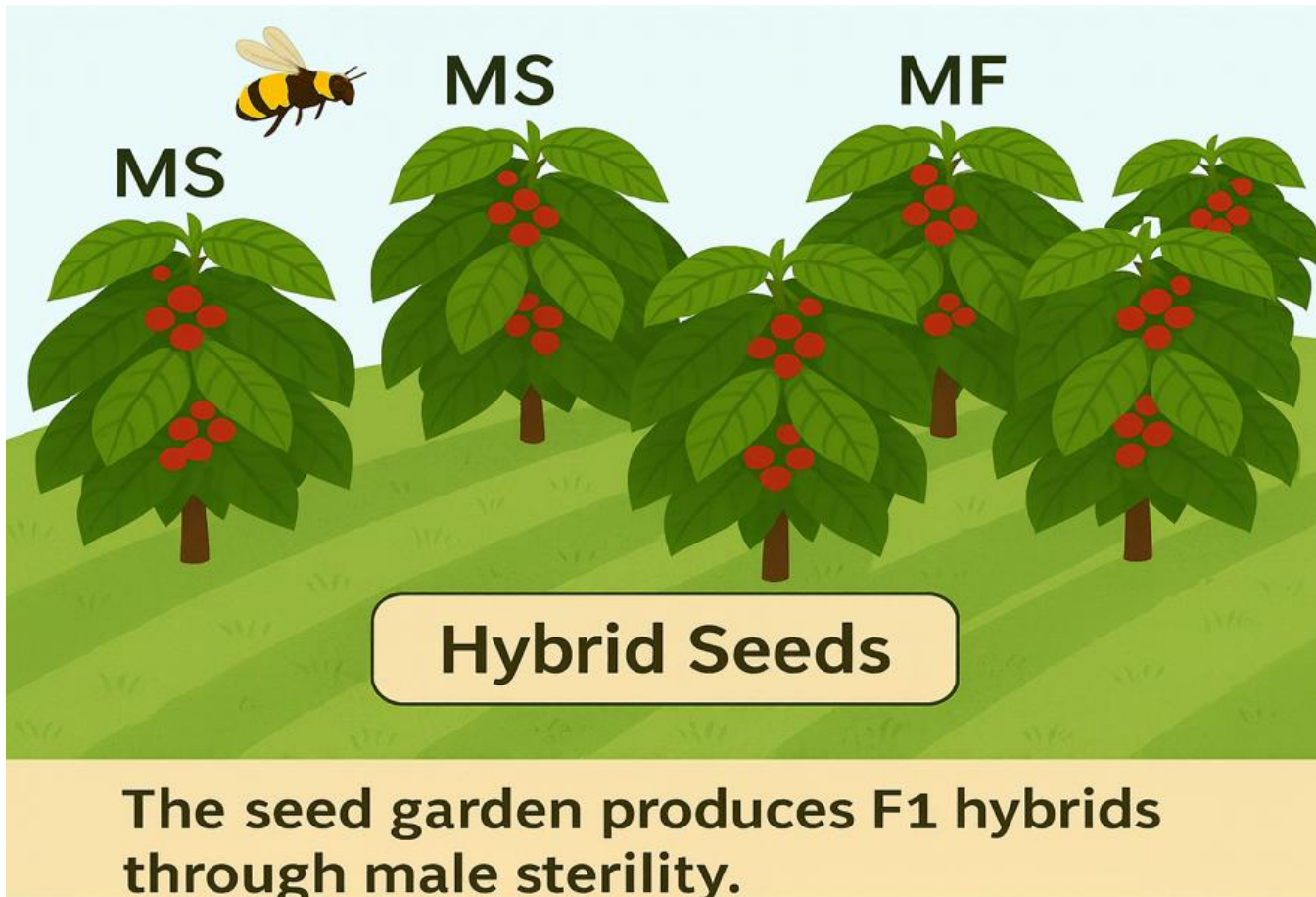
Mundo Maya (EC16)

Yield :+ 30-40%

Tree mortality after 15 years:- 10-25%

F1 hybrids seeds produced via male sterility

The cost of F1 hybrid seeds produced via male sterility is compatible with the majority of farmers' requirements, making them an affordable option for many.



4. Perspectives for delivering new varieties well-adapted to Global warming and future farming systems

The dual evolution of climate change and the automation of agriculture



Probable genetic gains in Canephora vs Arabica breeding over the next 10 yrs

Traits	C. canephora	C. arabica
Yield	Probable	Probable
Bean size	Probable	Probable
Bean chemical content (oil, caffeine)	Likely	Likely
Coffee cup quality	Probable	Likely
Adaptation to cooler environment	Likely	Likely
Adaptation to shade	Moderate	Likely
Tolerance to drought	Difficult	Difficult
Rust resistance /tolerance	Probable	Difficult
Dwarfism	Moderate	
Harvest mechanization (Uniform ripening)	Unlikely	Difficult
Adaptation to greenhouse (ultra dwarfism)		Moderate

Scale of difficulty

Probable

Likely

Moderate

Unlikely

Difficult

Canephora breeding

- Canephora has a remarkable intrinsic potential
- Its genetic diversity is very high and can be exploited in commercial clones
- Deforestation ?

Arabica breeding

- Arabica genetic diversity is very low
- Breeding for genetic resistance and tolerance to rust remains the primary objective.