# THE VARIETY COLOMBIA:

## A variety of coffee with resistance to rust
## *(Hemileia vastatrix* Berk. & Br.*)*


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ederación Nacional de
feteros de Colombia

SUBGERENCIA GENERAL TECNICA
CENTRO NACIONAL DE INVESTIGACIONES DE CAFE
"Pedro Uribe Mejía"

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# INTRODUCTION

This publication is intended for plant scientists and agricultural technicians interested in the problem of controlling coffee rust using resistant varieties.

The main objective is to present a clear summary of the process involved in the development of the variety Colombia, a cultivar resistant to *Hemileia vastatrix*, including a discussion of the problems and difficulties that occur often in this type of work, avoiding in the explanation the use of very elaborate jargon and scientific concepts.

This, then, is a guide for the agricultural professionals to teach the farmer the correct use of a new and valuable resource for growing coffee, i.e., the use of improved varieties.

## NECESSITY OF IMPROVED VARIETIES WITH RESISTANCE TO COFFEE RUST

The genetic uniformity of the varieties of coffee grown in Latin America is a fact well known and widely proven. Forty years ago two varieties were grown in almost all the area planted. They were called Arabiga or Típica and Bourbon. As is known the Típica variety was introduced into America in the 18th century. This variety originated from seed collected from only one plant grown in the botanical garden in Paris. Its uniformity has been proven in several experiments in Colombia and other countries of Latin America. Bourbon is originally from the Reunion Island and probably also derived from a few plants; its uniformity has been demonstrated in research inBrazil.

In the last decades, two new cultivars have become important. The variety Mundo Novo became very popular in Brazil, and the variety Caturra has occupied a considerable area in Colombia and in several countries of Central America. However, none of the varieties mentioned has the genetic diversity that the breeders require in their screening programs to face certain problems, especially of a pathological nature. Professor Wellman pointed out the general susceptibility to a considerable number of diseases and pests that these cultivars show, which is intimately related with their genetic homogeneity.

Among these diseases, the leaf rust caused by *Hemileia vastarix*, and the fruit disease caused by the fungus *Colletotrichum coffeanum*, are very notable because of their severity. The rust spread through Africa and Asia after 1880 but was absent from America until 1970, the year in which it appeared in Brazil. Since then coffee rust has been found in 11 countries including the majority of Central America and Colombia, where it was detected in September 1983.

The effect of rust in reducing production has been gradual. The cost of chemical control has increased as the disease has spread. An alternative that allows sustaining production and avoiding the cost of chemical control is the use of resistant varieties.

It is clear that the need is to create new coffee cultivars resistant to rust and with enough genetic variability to face not only this disease but also other potential threats.

# SELECTION OF VARIETIES RESISTANT TO COFFEE RUST

## Objetives and Dificulties

According to the classic text of plant breeding by R.W. Allard, the final goal of the breeder is to increase production. This can be reached in different ways. The adaptation of varieties to new areas of cultivation has been one of the most used ways. The most famous example of this is the adaptation of tropical species selected for the temperature zones. Another successful system has been the development of varieties with certain agronomic characteristics that make them more appropriate for intensive and mechanized cultural practices. Dwarf varieties are examples of great importance in the United States, in crops such as sorghum and especially wheat. Their use made possible the Green Revolution in developing countries. Another method that has given spectacular results in modern agriculture has been the use varieties resistant to pests and diseases, whose beneficial effects in the increase and stabilization of yields are similar to those obtained when cold, heat, and drought tolerance have been incorporated in crops of economic importance.

But not only production is involved in the breeding of plants; increasing product quality is necessary because the needs of the consumer, and also the technology of preserving, packaging, and storing the products.

In the selection of a coffee variety resistant to rust and adapted to the conditions of Colombia, several of these aspects have been considered. First, the characteristic of dwarfness was incorporated, which makes the improved varieties more efficient in the use of sunlight and land. Second, product quality is watched carefully. Seed defects inherited from the resistant parent or originated in the crossing process are reduced, and special care is taken to keep the excellent beverage quality that characterizes Colombian coffee. Third, more productive materials that show wide adaptation to different environments in the coffe zone are chosen. Finally, the new genotypes are watched carefully for susceptibility to other diseases.

Time is a decisive factor for completing this complex work, since the gradual, simultaneous selection of the mentioned characteristics decreases notably the probability of success, or prolongs considerably the process of selection. Also, one must consider that coffee is a semi-perennial crop and that the cycle of selection is prolonged for 7 or 8 years.

The management of resistance to *Hemileia vastatrix* presents a high degree of difficulty. *H. vastatrix* is a changing organism; it has the ability to vary its genetic constitution. The result of such changes is the appearance of new pathogenic races that can attack once-resistant varieties.

*Of thousands of plants, the best are selected for their characteristics of quality and disease resistance.*

In the development of new varieties, we are using a scheme of genetic diversity with which it is hoped pathogen variability will be faced with success. A variety with only one type of resistance will be uniformly vulnerable to a new virulent race of pathogen, without any genetic barrier to the dissemination of the pathogen. On the contrary, in a composite variety in which different types of resistance are present, only some components will be susceptible to a new race, and the variety's diversity will effect a barrier to the dissemination of the pathogen. Thus, the composite variety will buffer against the development of epidemics with explosive characteristics.*

*Promising materials are tested in different locations to establish their adaptation.*


* See "Genetic Diversity: Protection Against Epidemics", page 24.

# BREEDING SYSTEM

Since 1953, new genetic materials with rust resistance have been being introduced to Colombia. Their subsequent agronomic evaluation demonstrated that they carry undesirable genetic traits that make them less desirable for commercial use without a prolonged process of selection. Because of this, the transfer of resistance to commercial varieties emerged as a more convenient alternative. This transfer is made via crosses between rusts-resistant plants from Cenicafe's germplasm collection and high-producing commercial varieties with desirable agronomic characteristics. After a long process of selection through several generations, plants are selected within the progeny that combine good agronomic characteristics and resistance to rust. These plants are the basis for the multiplication phase.

# Progenitors used in crosses

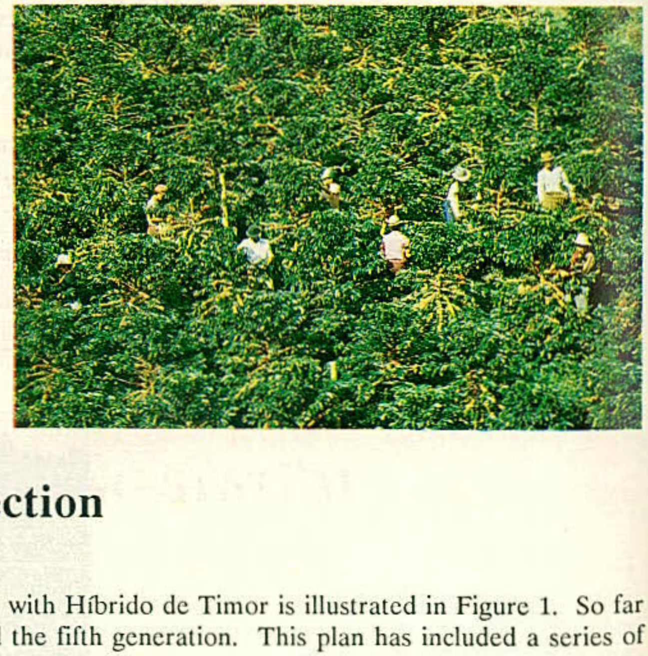
"Híbrido de Timor" was chosen as the basic progenitor carrier of rust resistance, for both scientific and practical reasons. Híbrido de Timor originated on the island of that name, probably from a spontaneous cross between *Coffea arabica* and *C. canephora*. Híbrido de Timor is a population of tall plants which, through some natural process, acquired the same number of chromosomes that characterize the arabica coffee, i.e. 44. Like other varieties of *C. arabica*, it is self pollinated. Also, it has several genes for resistance to rust, which is fortunate for the program adopted in Colombia since, in the process of crossing with varieties of *C. arabica*, new combinations of genes are formed in the descendants that assure an extensive genetic diversity.

In the mentioned crosses, preference is given to the commercial dwarf varieties because they are better for intensive cultivation. Besides this kind of plant facilitates harvesting and allows for more harvests before plants need renovation because of their excessive height.

Reduced height is controlled by dwarfness genes carried by several cultivars, but crosses with the varieties Caturra and Catuai (which possess them) are preferred because they have good agronomic characteristics in Colombia.


*Besides resistance to rust, Híbrido de Timor has other advantages that make it an appropriate parent to cross with susceptible varieties.*

*A variety with short height facilitates harvest and is more adequate for intensive cropping.*



# The process of selection

The breeding scheme followed with Híbrido de Timor is illustrated in Figure 1. So far selection has been continued until the fifth generation. This plan has included a series of backcrosses with commercial progenitors, with the objective of eliminating some undesirable characteristics. However, this process is used with less frequency because it is detrimental to obtaining resistance.

The materials that combine resistance to rust and promising agronomic characteristics are propagated separately. Later, mixtures are developed with seed coming from the best lines. The mixtures are released to farmers as a composite cultivar.

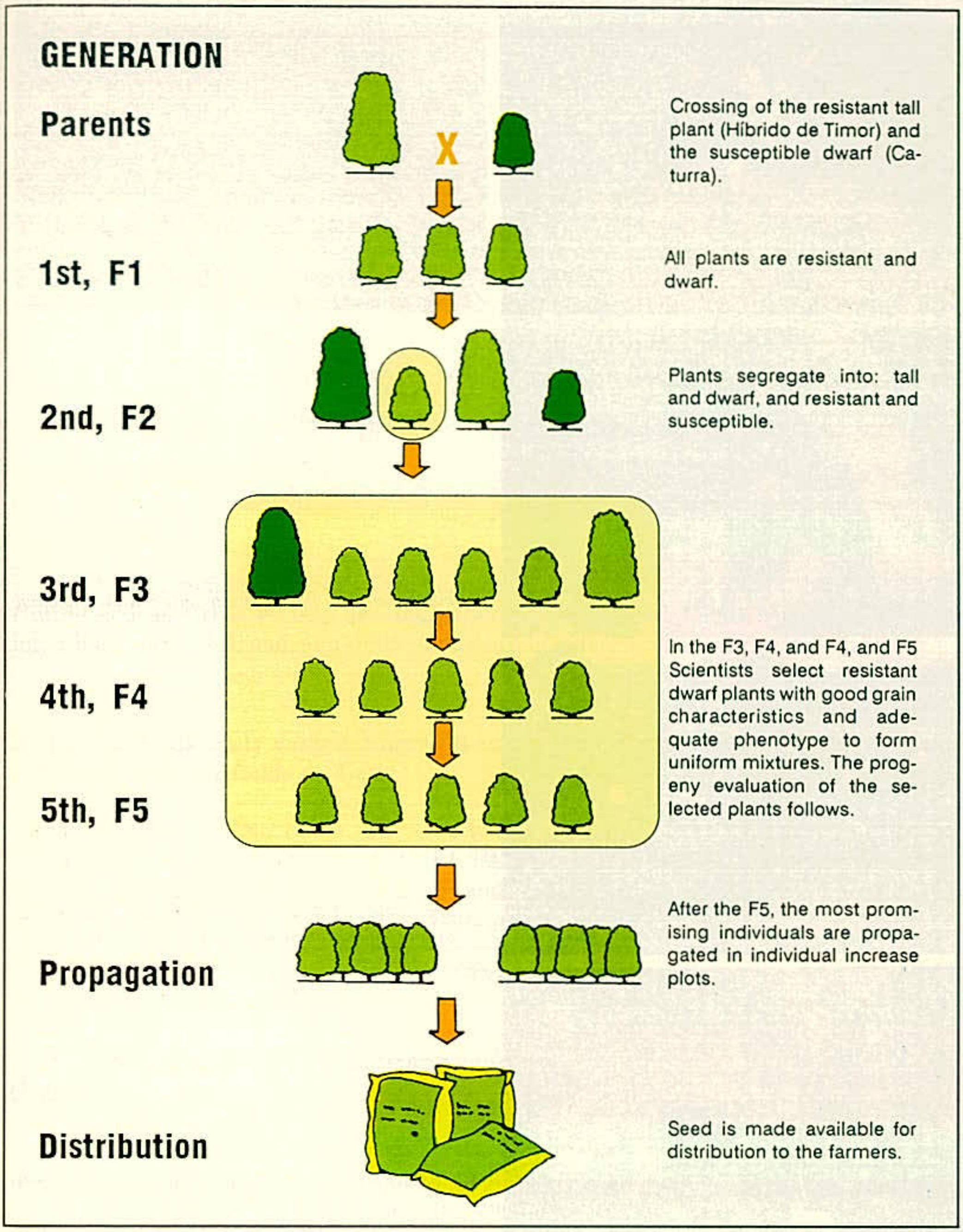



*FIGURE 1. Process of obtaining improved materials using Híbrido de Timor.*

*In the process of emasculation, anthers are removed from the mother plant.*

*For pollination, flowers are fertilized in the maternal plant.*

*The pollinated flowers are marked and protected to avoid contamination with extraneous pollen.*


*Resultant fruit from crossing*

*Seed from crosses give origin to new generations, which combine the characteristics of the two progenitors.*

Since 1968, numerous crosses have been made in Colombia between Híbrido de Timor (Introduced as CIFC #1343) and the varieties Caturra and Catuai. This program was intensified after 1970 and, as a result, thousands of plants are being evaluated (table 1).

TABLE 1. Materials derived from 1970 to 1985 from Colombia's breeding program with Híbrido de Timor.

| No. of Trials | No. of Plants | No. of F1, F2, F3 F4 and F5 Generations | No. of Backcrosses | No. of Complex crosses |
|---|---|---|---|---|
| 53 | 28,570 | 736 | 235 | 54 |

After the third generation, yield comparisons are made in nine locations in the coffee zone (Figure 2).

In the descendants of the crosses, great variation is released for traits of economic importance such as yield, vigor, adaptation to different zones, characteristics of the grain and the beverage, and others of secondary importance such as ramification type, and form, color, and size of leaves, etc. All the characters mentioned are registered plant by plant several times a year for five season.

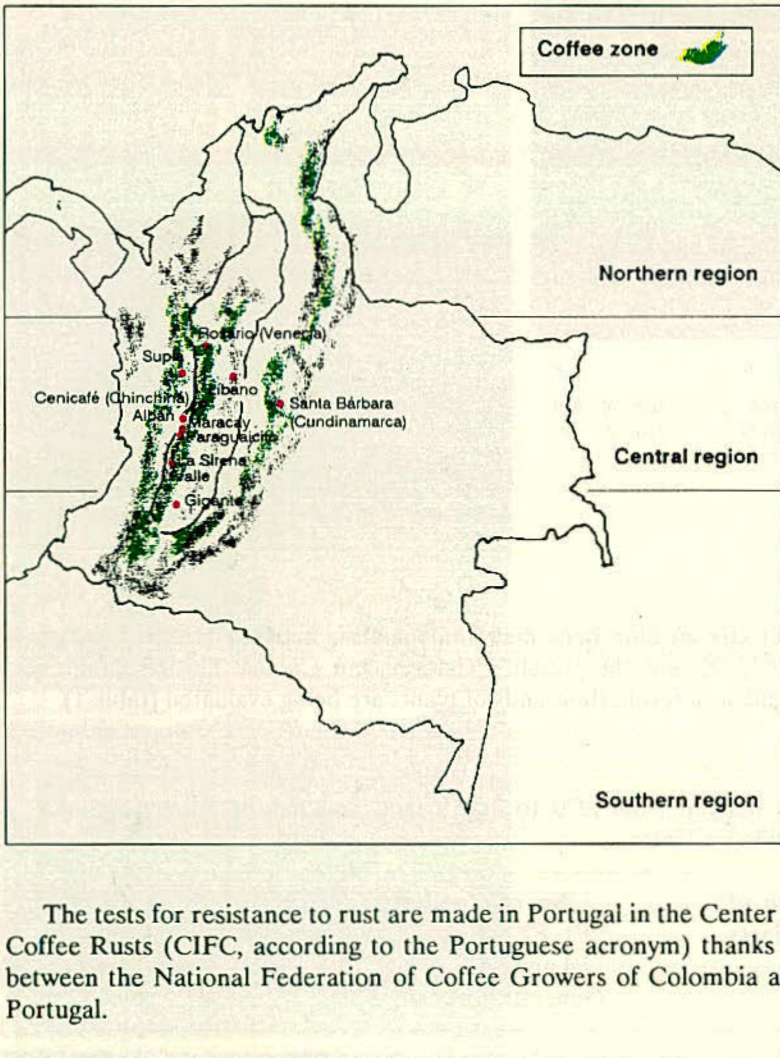



*Figure 2. Location of the experimental sites.*

The tests for resistance to rust are made in Portugal in the Center for Investigation of the Coffee Rusts (CIFC, according to the Portuguese acronym) thanks to a treaty established between the National Federation of Coffee Growers of Colombia and the Government of Portugal.

Small plants (chapolas) from selected trees in the Colombian experiments are sent to CIFC where they are inoculated with all the races of *H. vastatrix* that exist in the collection of that institution (Photographs, page 13).

After inoculation, the seedlings are classified into "physiologic groups" according to their reaction of resistance or susceptibility.

The results of these tests are used to identify the trees in Colombia that produced the progeny with resistance and that are more useful. The work of breeding and selection is continued with them.

*

*The collection of races of* **Hemileia vastatrix** *is mantained along with the differential varieties in the Center for Investigation of Coffee Rusts (CIFC) in Portugal.*

*Inoculation of coffee with races of the pathogen constitutes the test for resistance in the improved materials.*

*

*Conditions of humidity and temperature appropriate for the fungus must be maintained to assure the success of the inoculation.*

*

*The clear reaction of the susceptible check guarantees the safe selection of the resistant material.*

** Marcelino Lima Rodríguez, Photographer*

## SOME IMPORTANTS RESULTS

## Plant architecture

In considering plant architecture, the most important aspect of the program is the reduction of plant size. The selection for reduced height is practiced until the third generation by which time homogeneous progenies can be obtained with this characteristic.

A group of 30 progenies of the fourth generation of the cross Caturra x Híbrido de Timor, to which the genes for dwarfness are being incorporated, are used to illustrate the height of this population. In Figure 3, the F4 progenies and the varieties of low height form populations with equivalent height since the average variation in height is very similar. At some sites, the difference between the F4 progenies and any of the checks is statistically significant, but in no case does this have practical importance. This indicates that while making a mixture of the F4 progenies, a population will be formed with an acceptable degree of variation for height, and that the mixture can be planted at the same spacing used with the varieties Caturra and Catuai.

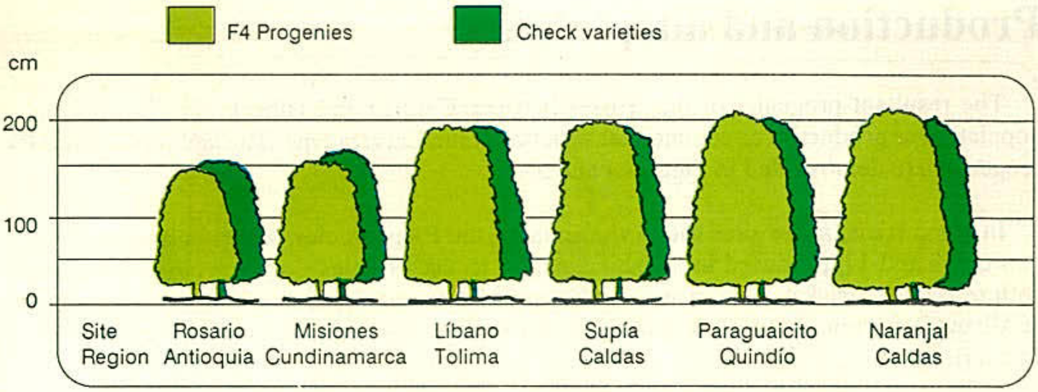



*FIGURE 3. Medium height of the F4 progenies and short-statured check varieties after 36 months, from different locations.*

Other aspects of plant architecture that must be kept in mind are the type of branching and the form, size, and color of the leaves. For these characters, there is a notable variation among the descendants of the crosses of Caturra and Híbrido de Timor, but types intermediate between the characteristics of the parents predominate. Plants more similar to the "Caturra" type are selected from among the best agronomic types. This has resulted in the predominance of Caturra characteristics in the advanced generations.

*The progenitors are selected by their similitude with Caturra variety.*

# Production and adaptability

The resultant progenies of the crosses between Caturra and Híbrido de Timor, form a population as productive as commercial varieties of the Caturra type. The yields of F3 and F4 progenies are demostrated in Figures 4 and 5.

In seven trials in five sites within the country, the F3 progenies, which in number varied between 7 and 17, produced in a fashion similar to the varieties Caturra rojo and amarillo. Differences occurred at random and in extreme cases were only 16% in favor of the progenies in Alban (Department of Valle), and 14% in favor of the checks in the Libano (Department of Tolima).

It must be emphasized that one objective of the trials is to select only the best progenies. To effect this selection, scientists take as a limit the production of the checks. As is shown in Figure 4, in all the sites there were progenies with production similar or superior to that of varieties of the Caturra type.

A similar situation occurs in the F4 progenies that are being tested at 6 locations in the sense that, at all the sites, there are progenies similar or superior to the progenies of Caturra type (Figure 5).

Not only are the F3 and F4 progenies productive materials, but they also show a high level of genetic variability, which will allow the selection of new types that possibly will exceed the current production level. Some of the progenies studied are well adapted to a wide zone of the country; at all sites where they have been tested, they stand out for their high production (Figure 6).

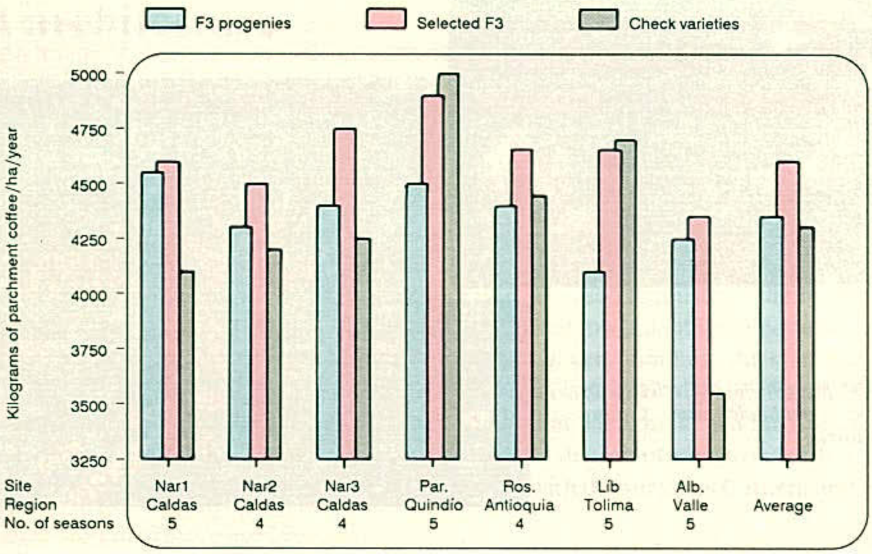



*FIGURA 4. Average yield of the F3 progenies of Caturra x Hibrido de Timor and check varieties, from several sities.*

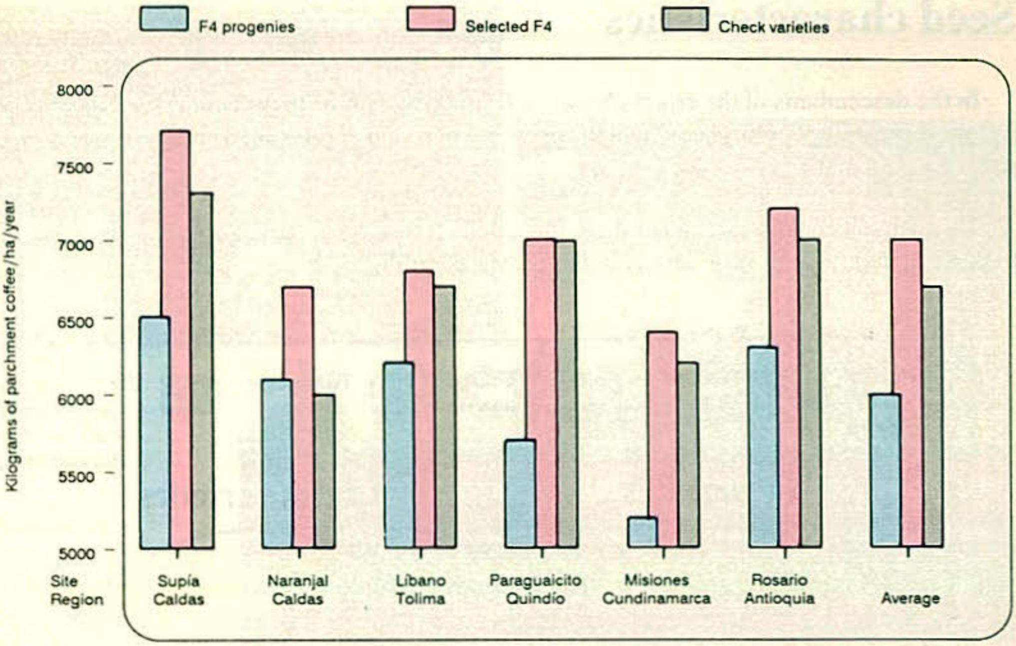



*FIGURA 5. Average yield for 4 seasons, of F4 progenies of Caturra x Híbrido de Timor and check varieties, from several sites.*

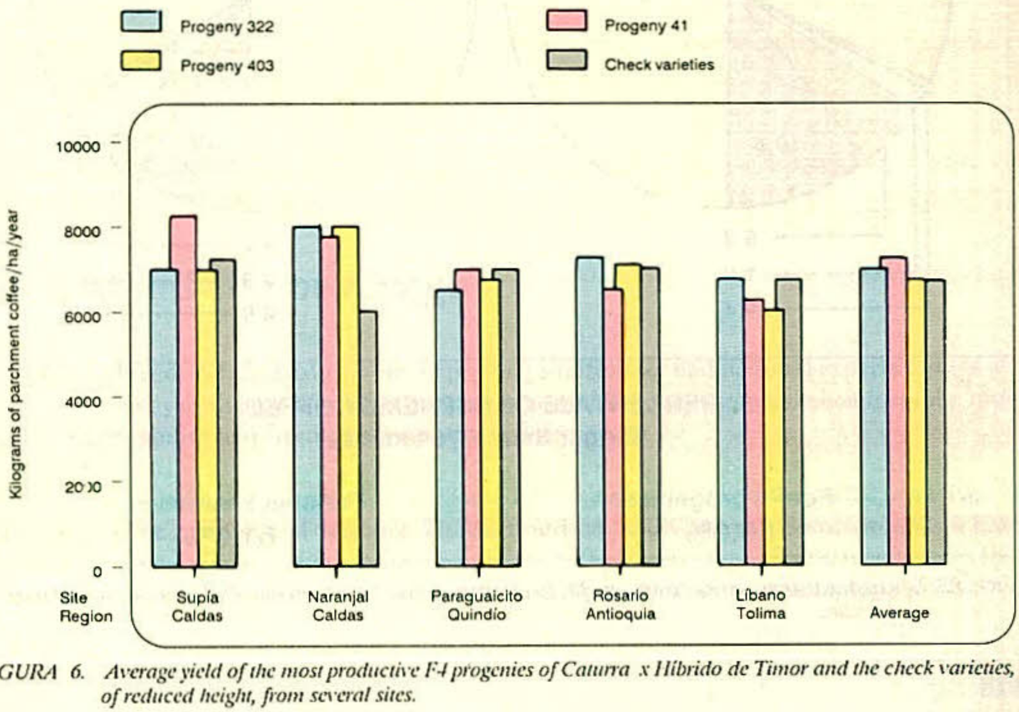



*FIGURA 6. Average yield of the most productive F4 progenies of Caturra x Híbrido de Timor and the check varieties, of reduced height, from several sites.*

## Seed characteristics

In the descendants of the crosses between Caturra and Híbrido de Timor, seed defects are common, including "empty seed" and the presence of round grains called peaberries, and small size.

Through selection in each generation, these defects have been reduced to levels comparable to those in commercial varieties, as is demonstrated in Figure 7.

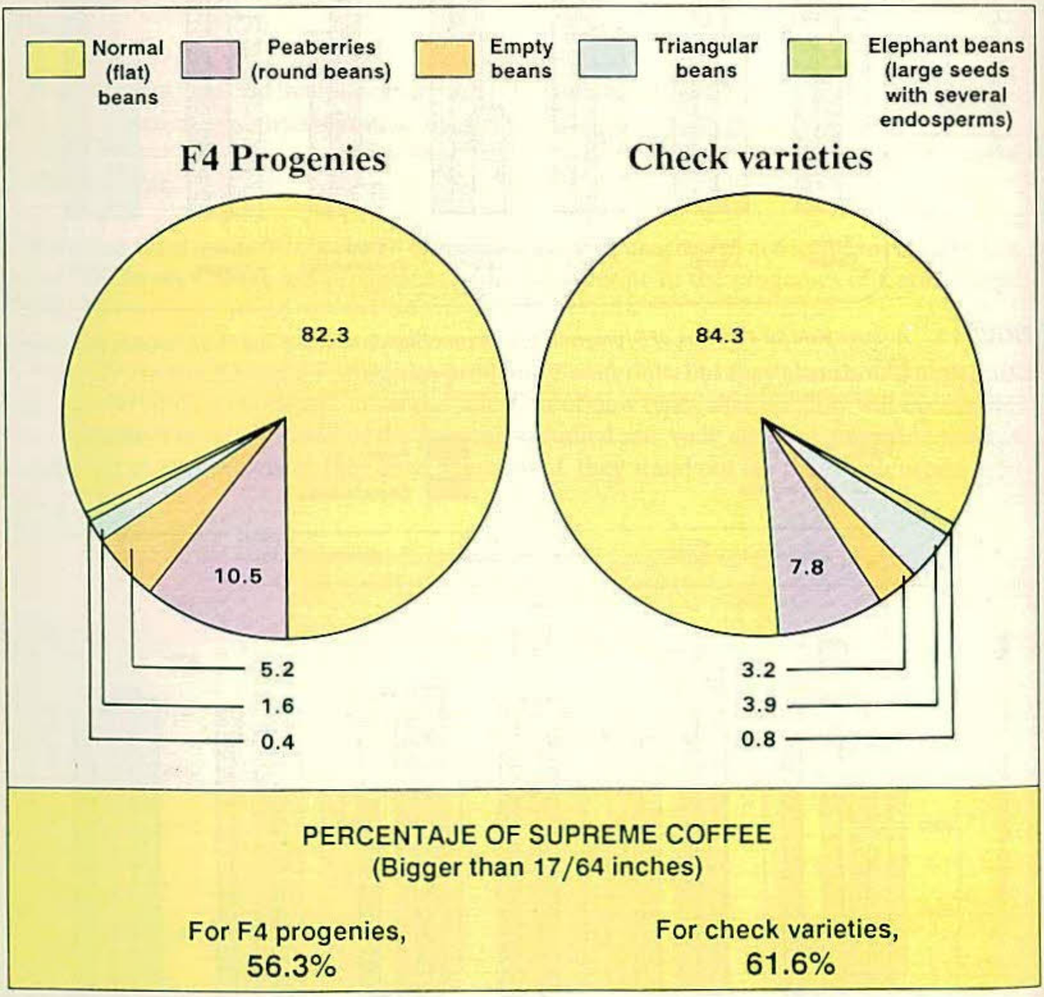
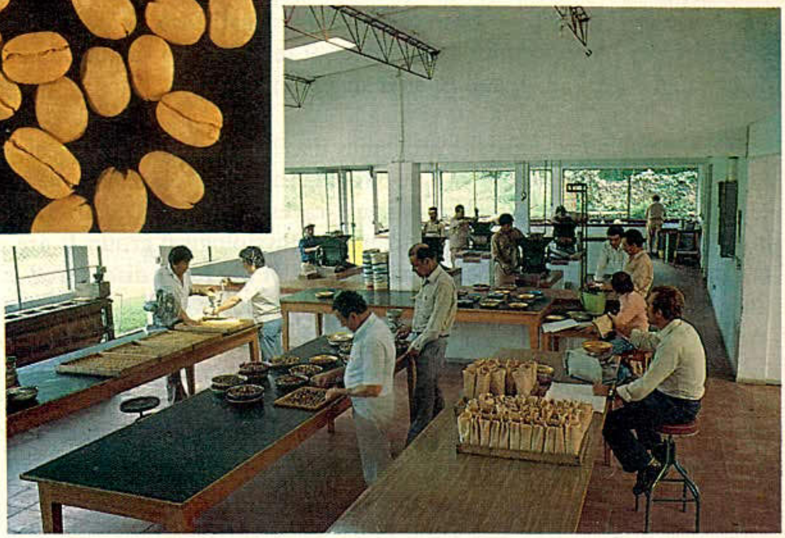



*FIGURE 7. Characteristic of the grain in 30 F4 progenies of Caturra x Híbrido de Timor and in commercial varieties.*



*Through analyses of numerous samples,characteristics of the seed of the experimental material are evaluated in the laboratory.*

# Quality of the beverage

For the test of coffee quality in the cup, groups of foreign and national experts tasters are employed. They evaluate the acidity, body, aroma, and flavor of samples taken from the most advanced progenies and from check commercial varieties.

The results indicate that most of the F3 and F4 progenies tested produced the same type of beverage as the commercial varieties Típica, Bourbon, and Caturra. Some progenies have received the same classification for export as coffee of the Excelso type. These results show that there won't be any objection about the quality in the cup of the improved materials.

# Resistance to rust

Thousands of seedlings belonging to hundreds of families derived from the cross of Caturra x Híbrido de Timor have been tested in Portugal since 1970. The reactions of resistance or susceptibility have permitted the material tested to be classified into 6 physiological groups designated A, 1, 2, 3, 4, and E, as is shown in Figure 8.

Of special interest are the progenies that belong to physiological group A because they are not attacked by any race identified to date. In second place, are the ones that belong to groups 1, 2, 3, and 4 that are attacked by some races of the CIFC collection, but these races are not present in America. The descendants of physiological group E are of the least value in the program because they are susceptible to all of the races discovered in America. Fortunately, these plants have very little disease in comparison with the check varieties.

An important fact is that the proportion of plants from group E is notably low, less than 6%, which would make chemical control unnecessary. Besides, in the general program, the progenitors that produce descendants of group E are eliminated. In this way, the proportions of plants in the field susceptible to the most common races could be reduced to near zero.

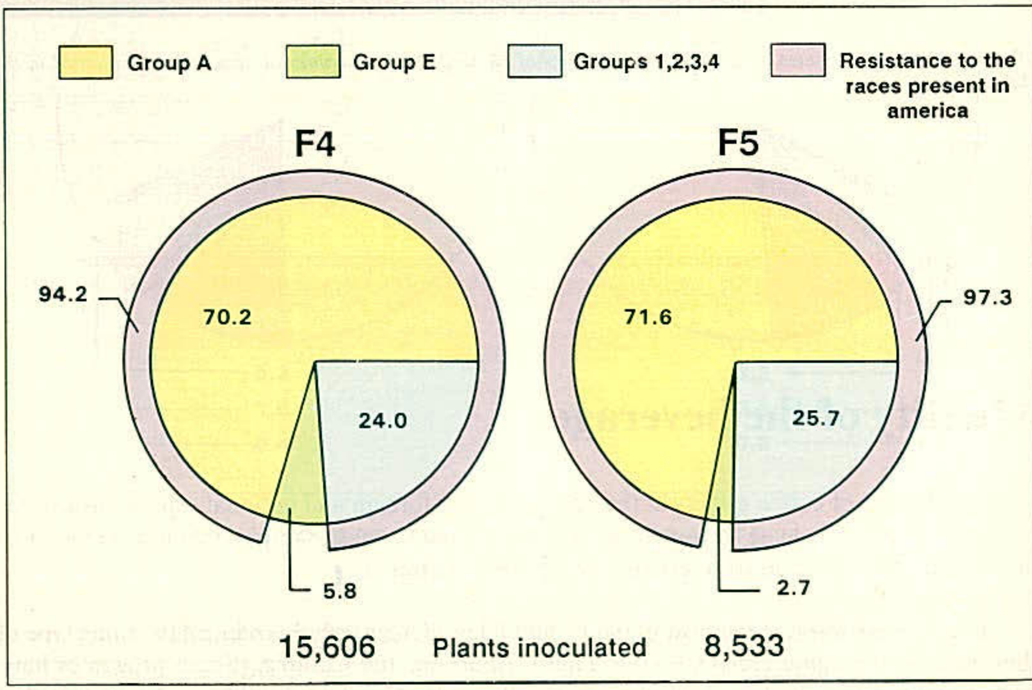



*FIGURE 8. Percentage distribution of physiological groups in F4 and F5generations of Caturra x Híbrido de Timor, tested in Portugal against* Hemileia vastatrix *until 1981.*

# PROPAGATION AND DISTRIBUTION OF SEED

As a result of the process described, Colombia has been able to develop, in the absence of coffee rust, valuable materials resistant to rust that possess the minimum requisites for intensive cropping: low plant height, enough phenotypic homogeneity, good yield and grain characteristics, and beverage quality similar to that of the commercial varieties.

A plan of propagation and distribution of seed of this material has been established. The plan is shown in graphic form in Figure 9. The outstanding progenies are studied in detail in trials at different sites of the country, and at the same time the most outstanding progenies are propagated in separate plots on several farms chosen for this purpose. Currently, there are 56 hectares of seed increase fields located in the Departments of Quindío, Tolima, Valle, Antioquia and Cundinamarca.

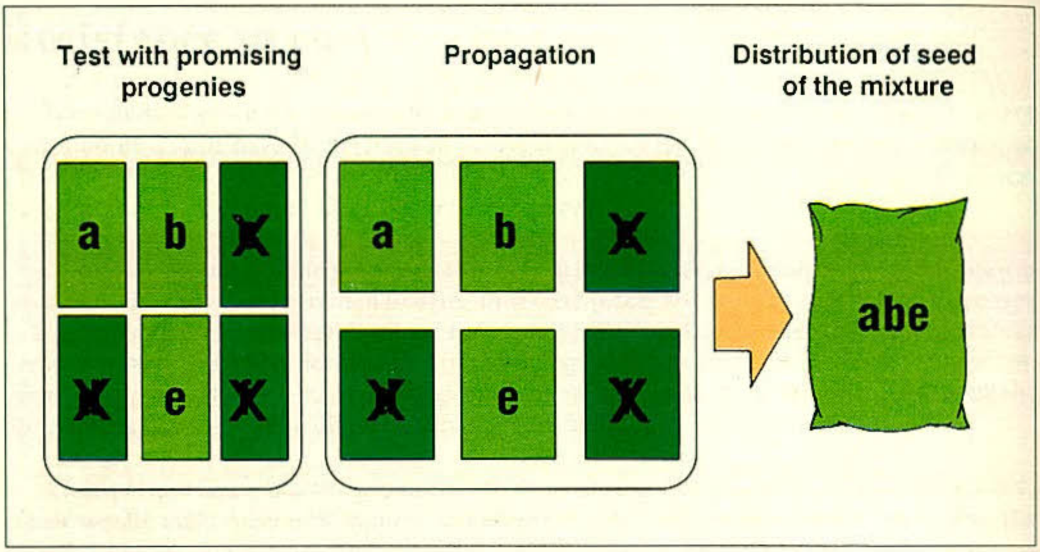



*FIGURE 9. Scheme of tests, propagation, and distribution of the seed.*

Using the seed produced by the best progenies, a mixture is formed that is a heterogeneous variety with acceptable phenotypic uniformity and great diversity for resistance to rust. The diversity portends its stability against races of the pathogen that may arise in the future.

This mixture, or composite cultivar, has been distributed to farmers since 1983 with the name of **VARIETY COLOMBIA.**

*The elite material being propagated in isolated blocks at five locations.*

# Obtaining seed for planting

The character of the composite Variety Colombia requires a change in the practice previously used by the farmer for getting seed. Always, when new plantings are made of the Variety Colombia, seed produced by the National Federation of Coffee Growers must be used. Farmers must avoid the use of seed that originated on private farms, for the following reasons:

a. The planting seed distributed by the National Federation of Coffee Growers is a mixture of seed from numerous progenies that were selected for this purpose, i.e., to keep the great diversity for resistance to rust and to protect the variety against new races. If seed from commercial plantations is used, there is a risk of drastically reducing diversity.

b. Every time new and better resistant materials are selected, they will be incorporated into Variety Colombia to enrich it. It is obvious that this cannot be done if the seed comes from commercial coffee plantations.

c. When races of the rust arise that are able to attack any component of the Variety Colombia, that component will be withdrawn from the mixture and replaced with other resistance. Thus, seed produced by the National Federation of Coffee Growers will keep "current" Variety Colombia's resistance to rust.

## GENETIC DIVERSITY: PROTECTION AGAINST EPIDEMICS

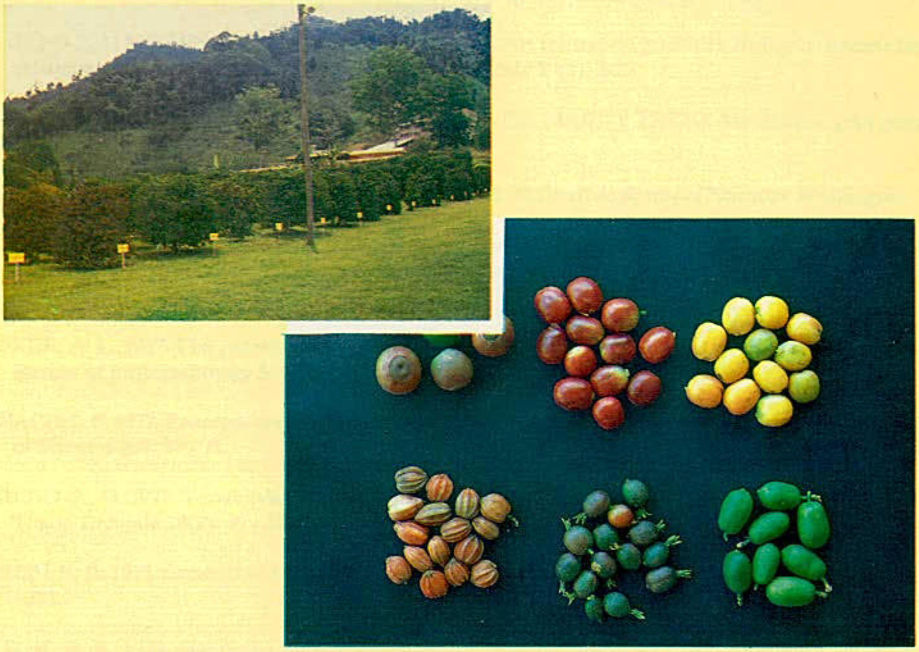
Since long ago, the centers of origin of the main crops have called for the attencion of researchers because, in them, there exists a pathological equilibrium that impedes the development of epidemics of an explosive character. Scientists suggest that, to reach an equilibrium in which the host and pathogen live harmoniously, the great genetic diversity of the plants in their regions of origin is the decisive factor.

In the wild state, cross pollinated species keep their great diversity as a result of their high percentage of cross pollination. In this condition, natural selection works in favor of the resistant genotypes most able to survive. In species in which self pollination predominates, diversity also occurs, and, due to natural selection, numerous genetically different lines arise and form a heterogeneous population.

While developing improved varieties, there has been a tendency to select and utilize very few (only the best) progenitors, which has contributed to forming genetically uniform populations. The extreme homogeneity of these new cultivars has been associated with vulnerability to diseases. In these cases, when a pathogen breeds a new race able to attack the variety, all the plants are susceptible. A plantation of this type has been compared to a dry prairie. A spark can initiate a fire that expands without any obstacle through all the prairie; in the same way, a disease can rapidly devastate a homogeneous variety.

The way to increase the genetic variability in a variety homogeneous and vulnarable to epidemics has been a matter of priority in cereal breeding during the last 30 years. An answer to this problem has been the multilines. They are formed by a mixture of seed coming from lines similar in agronomic characteristics, but different in rust resistance, because they carry different genes. When a race of the pathogen attacks one or several components of the multiline, others remain healthy, because their types of resistance are not compatible with such a race. But multilines also protect because they function as barriers to pathogen dissemination. In this way many susceptible plants remain healthy.

The mixture of different types of resistance acts also as a shock absorber to the attacks of the disease. On the whole, the rate of pathogen dissemination is decreased and the plantation and the plantation can produce before suffering severe damage.



*The variability that exists in germplasm collections is used to obtain new improved genotypes.*

It has been said that the mixture of different resistant genotypes in the multilines can cause the rapid appearance of a race pathogenic to all the component lines. The experience with the use of oat multilines in the USA and of wheat in different countries has not confirmed this assumption. On the contrary, it looks like the multilines can reduce or at least stabilize the rate of appearance of new pathogenic races.

In conclusion, genetic diversity plays a relevant role in the equilibrium of hosts and pathogens, and this action seems to be a common rule in nature. For this reason, the principles of diversity are applicable in general to plant breeding, especially in situations where durable and stable resistance is required. In the case of coffee, it is prudent to follow the advice of Dr. Browning, a well known researcher in breeding for disease resistance, in the sense of "using as much genetic diversity as possible, without sacrificing either yield or quality"

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