Diploid Breeding at FHIA and the Development of Goldfinger (FHIA-01)

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Introduction

In 1959, executives of United Fruit Company had just witnessed the final elimination of the Gros Michel banana variety by race 1 of Fusarium wilt. Fortunately, the Cavendish clones are resistant to race 1 and were planted to save the export industry. However, no other natural variety would be available to replace Cavendish if it too were later destroyed by an uncontrollable disease. These farsighted men started the current FHIA breeding program (the program was donated to the Fundación Hondureña de Investigación Agrícola (FHIA) in 1984) to develop a “man-made” banana which would be resistant to such an anticipated new disease. This disease now exists in the form of race 4 of Fusarium wilt. In addition, black Sigatoka has the potential to eliminate Cavendish for export and the burrowing nematode could greatly reduce productivity. Black Sigatoka could become resistant to all approved fungicides which are used as chemical control measures, and additional nematicides could be banned (two have already been banned by regulatory agencies) due to their dangers to consumer health and the environment.

While protection of the export trade was the main reason for beginning the breeding program, the hybrids developed in this program now also provide the only practical solution to the drastic yield reductions (up to 50%) presently being caused by black Sigatoka on the plantains and cooking bananas grown for local consumption. About 90% of the world production of bananas and plantains is for domestic food, and most of the major producing areas have become infested with this disease in the last few years.

Current financing of the breeding program is by the International Development Research Centre (IDRC) of Canada, the Windward Islands Banana Growers’ Association (WINBAN), the government of Honduras, the government of Ecuador, the Natural Resources Institute (NRI) of the United Kingdom, and the United Nations Development Program/International Network for the Improvement of Banana and Plantain (UNDP/INIBAP).

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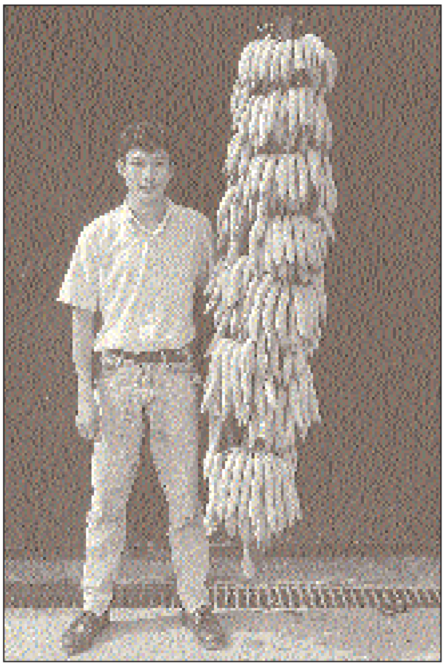
Figure 1: *Bunch features of the SH-3723 diploid which is being used as a parental line in breeding for multiple disease resistance. SH-3723 is resistant to black Sigatoka and has resistance to race 4 of Fusarium wilt and the burrowing nematode in its pedigree from both its SH-3248 and SH-3362 parental lines.*



Diploid Breeding – History and latest developments

The most important activity in banana and plantain breeding has always been development of agronomically superior disease-resistant diploid hybrids. These diploids are the main source of genetic variability in breeding new commercial-type hybrids since the triploids they are crossed onto are fixed in terms of genetic make-up. Progenies from crossing diploids onto the different seed-fertile triploid banana, plantain and cooking banana clones are tetraploids. Selected tetraploids are evaluated as potential new commercial hybrids or as parental lines in subsequent cross-pollinations.

Development of SH-2095, which was the first diploid with outstanding bunch features, was the result of the most exhaustive efforts which have been made in the different facets of genetic improvement. SH-2095 was the one agronomically superior hybrid selected during the first ten years of the program, and it is in the pedigrees of most of the subsequent diploids which have been selected from the segregating populations.

The hybrid which required the second most intensive cross-pollinations for its development was the SH-3142 nematode-resistant diploid. SH-3142 was the one hybrid selected from the few obtained by pollinating 10,000 bunches of the almost sterile Pisang Jari Buaya accession which is resistant to the burrowing nematode. In contrast to Pisang Jari Buaya, SH-3142 is readily usable as both a pollen and seed parent in cross-pollinations.

In addition to being resistant to the burrowing nematode, SH-3142 was found to be resistant to the race 4 of Fusarium wilt from Taiwan in the initial screenings for resistance to this disease. This hybrid is one of the parental lines of the SH-3362 diploid which is resistant to the race 4 in Australia. Now, a commercial-type tetraploid hybrid derived from crossing SH-3142 onto the Dwarf Prata triploid has shown apparent resistance to race 4 in Australia. This tetraploid, which has been given the code name of FHIA-01, is of vital importance since race 4 has the potential to destroy the current Cavendish commercial cultivars and the only control measure for this disease is genetic resistance. FHIA-01 is discussed in detail later.

Individual diploid hybrids with improved bunch characteristics and resistance to one particular disease have been available for several years. A primary objective in diploid breeding has been to develop agronomically superior hybrids with multiple disease resistance. The outstanding parental line for this series of crosses is the recently selected SH-3723. SH-3723 has exceptional bunch features (Fig. l) and has possibilities of being resistant to the two major diseases and the burrowing nematode. It is known that SH-3723 is resistant to black Sigatoka and resistances to race 4 of Fusarium wilt and the burrowing nematode are in its pedigree from both its SH-3248 and SH-3362 progenitors.

The one weakness of SH-3723 is that it has poor pollen and cannot be used as a male parent. It was learned this year that this hybrid produces an average of about two seeds per bunch when pollinated, and it is being multiplied for massive pollinations to obtain adequate quantities of progenies for subsequent evaluation and selection. It is expected that some of the hybrids produced from crossing onto SH-3723 will have the desirable agronomic and disease resistance features of this parental line and be pollen-fertile. Such selected hybrids with SH-3723 parentage would provide possibilities for using them in cross-pollinations onto seed-fertile triploids to develop new commercial-type bananas, plantains and cooking bananas with multiple disease resistance.

The inherent danger in having only one source of resistance to a disease is that no alternative would be available if the pathogen were to become capable of attacking that source. However, the poor bunch features of most of the accessions which provide an array of genetic diversity for disease resistance have handicapped development of agronomically superior hybrids from the different sources of resistance. All the accessions which are resistant to black Sigatoka have very inferior bunch characteristics. Until last year, the only bred diploid which was resistant to black Sigatoka and also had advanced bunch features was SH-3437. The resistance of SH-3437 came from the IV-9 accession of *Musa acuminata* ssp. *burmannica.*

Last year, the SH-3681 diploid with the II-357 *M. a.* ssp. *malaccensis* genes for resistance to black Sigatoka was selected after exhaustive long term efforts to incorporate the resistance of this accession into hybrids with improved bunch qualities. Development of SH-3681 is considered a major accomplishment in providing an additional breeding line with resistance to this disease. However, in view of the current difficulty and expense in controlling black Sigatoka, additional sources of resistance would give even greater security for breeding resistant commercial hybrids.

The first progenies from cross-pollinations between agronomically superior diploids and the parthenocarpic Lidi and two wild *M. a.* spp. *siamea* accessions which are resistant to black Sigatoka were evaluated this year. Positive results from these crosses readily indicate the value of the SH-3362 diploid (which has an outstanding bunch size) for crossing with these resistant accessions which have inferior bunch features. The influence of SH-3362 is expressed in the bunch features of SH-3745 which was derived from the 1-131 (*siamea*) x SH-3362 cross. SH-3745 is highly resistant to black Sigatoka and was selected out of a population of 250 segregating hybrids from crosses onto the I-131 and II-334 (*siamea*) accessions. By contrast, the SH-2989 diploid (which was derived from crosses onto the *burmannica* accession several years ago) was the only plant with an improved bunch from a population of 2,500 hybrids. From further crosses with SH-2989, the exceptional black Sigatoka-resistant SH-3437 diploid was developed. Similarly, now that SH-3745 has provided the *siamea* genes for resistance in a hybrid much superior to the accessions, it is expected that further crosses with SH-3745 will also result in outstanding hybrids with this new source of resistance.

Figure 2: *Plant of FHIA-01 growing without chemical control for black Sigatoka and supporting a 45 kg bunch with no propping. FHIA-01 was derived from Dwarf Prata x SH-3142 and is the first bred tetraploid with the combinations of disease resistance and agronomic qualities which make it an outstanding candidate for commercial plantings.*

A total of 21 additional diploids were selected from the segregating populations this year. Seven of these selections were from the SH-3437 x SH-3362 cross made in breeding for resistance to both black Sigatoka and race 4 of Fusarium wilt.

Breeding Apple-Flavored Bananas

In Asia, Brazil, and Australia where consumers have a choice between Cavendish and the apple flavored (more tart) fruit of the Prata and Silk cultivars, the latter is preferred. All the clones which have this apple-like flavor are susceptible to Fusarium wilt and have small bunches. Thus, they are not suitable for export.

The Dwarf Prata (AAB) clone was brought from Brazil in 1981 for evaluation as a fixed triploid parental line in breeding disease-resistant hybrids with this unique flavor. Now, the SH-3481 hybrid, which was derived from crossing the SH-3142 nematode-resistant diploid onto Dwarf Prata, is considered to be the best tetraploid produced to date. This hybrid was given the code name of FHIA-01 for its entry in the International Musa Testing Program (IMTP) sponsored by INIBAP for testing the reaction of seven FHIA hybrids to black Sigatoka in six Latin American and African countries. FHIA-01 is popularly known as Goldfinger. Its exceptional plant and bunch features (Fig. 2) with no treatment to control black Sigatoka make FHIA-01 an excellent candidate to become the first bred hybrid to be grown commercially.

The desirable features of FHIA-01 include the following:

1. Resistant to race I of Fusarium wilt (from observations by Ken Pegg in Australia).
2. Highly resistant to black Sigatoka (this resistance has now been demonstrated in Honduras, Costa Rica, Colombia, Cameroon, Nigeria and Burundi in IMTP).
3. Resistant to race 4 of Fusarium wilt (from observations by Ken Pegg in Australia).
4. Tolerance to the burrowing nematode (from observations by Ken Pegg in Australia).
5. Large bunch size.
6. Strong plant (plants support large bunches with no propping).
7. Good plant architecture (leaves are not droopy as in some tetraploids, and suckering is excellent for subsequent crops in the same stool).
8. Good post-harvest green life (this essential quality for shipping is about equal to that of Cavendish).
9. Strong neck (fingers do not detach prematurely from the cluster crown when ripe).
10. Apparently resistant to crown rot (from observations when compared with Cavendish in post-harvest trials).
11. Good flavor (the flavor is distinctively more tart than Cavendish when first ripened and becomes similar to Cavendish in the advanced stages of ripeness).
12. Diced fruit does not oxidize (Cavendish fruit turns an unsightly brown color when cut into pieces for dishes

such as fruit salads, but FHIA-01 fruit remains an attractive golden yellow).

13. Cold tolerant (plants remain green at low temperatures which cause Cavendish to become yellowish in Australia).
14. Ripens to a golden yellow without refrigeration or ethylene treatment (this trait is important for attractiveness of fruit for domestic consumption in areas where ripening rooms are not readily available).
15. Excellent flavor and texture when boiled green (this makes this hybrid an attractive dual purpose banana for certain regions).

FHIA-01 has a plant height very similar to that of the semi-dwarf Valery which was the most widely grown Cavendish cultivar before it was replaced by the shorter Grande Naine. However, FHIA-01 is a stronger plant than Grande Naine and this plant sturdiness is expected to compensate for the taller height in withstanding damage from strong winds. In other comparisons with Grande Naine (which is receiving the prescribed chemical disease control treatments), FHIA-01 is slightly slower to flower and the fruit reaches harvest grade about two weeks later. However, the productiveness of FHIA-01 is far superior to that of Grande Naine if no fungicide or nematicide applications are made.

The disease-resistances and hardiness of FHIA-01 could result in its being even more important for domestic consumption than for export. It can be grown by small holders in countries where Cavendish could not be grown because the expensive pesticides required were beyond the economic means of these farmers. In addition to the six countries already mentioned where it has been tested in the IMTP plots, this hybrid is being evaluated extensively in Australia. It has also been distributed to many other countries by INIBAP for local evaluation. Indeed, FHIA-01 could soon become the universal dessert banana, especially since it also has shown tolerance to marginal soil fertility conditions and extended periods of inadequate rainfall.

To illustrate the potential impact of FHIA-01 in East Africa where boiled or steamed cooking bananas are a dietary staple for 20 million people, bunch sizes of this hybrid are about twice as large as those of the popular Nyamwihogora East African cooking banana at sea level. If FHIA-01 is adapted to the higher altitudes of this region, it could be a productive black Sigatoka-resistant cooking as well as dessert banana. Dessert bananas are not currently readily available in East Africa since their traditional highland cooking bananas are not very appetizing for eating raw when ripe.

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Latin America

Plantain in Central Colombia

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The main coffee and plantain zone in Colombia is the center of the country with nearly 300,000 ha of coffee and about 110,000 ha of intercropped plantain producing some 1,400,000 tonnes for domestic consumption. The region includes the administrative departments of Caldas, Risaralda and Quindio and part of the Cauca river valley. The area is fairly mountainous (Andean system). Agriculture is well developed and adapted to local conditions. Coffee and plantain grow from 1,000 to 1,800 m above sea level, implying considerable variation in environmental conditions. It is also one of the highest plantain production zones in the world.

Soil and climate are extremely favourable for plantain development and account for continuous plant productivity even with minimum crop maintenance. Most soils (70%) are derived from recent volcanic ash and have a high organic content (often over 8%); fertility is medium and, although they are fairly sensitive to erosion, serious problems are avoided by good management. Climatic features are annual precipitation of about 2,000 mm spread regularly throughout the year and 1,600 to 1,800 hours of sunshine per year. Temperature is the most variable factor, oscillating between 18 and 21°C; amplitude can reach 18 to 27°C according to altitude.

The importance of plantain in the zone is more social than economic or agronomic. Farmers devote their resources and efforts to coffee and only occasionally spend time on plantain. In spite of this, the impact of plantain on job creation and complementary income is far from negligible.

A project entitled "Improvement of plantain cultivation in the central coffee zone" was initiated in 1990 through collaboration between three institutes: CIRAD-IRFA[1] (France), the Federación Nacional de Cafeteros de Colombia (FNCC) (Colombian National Coffee Producers Federation) and the Instituto Colombiano Agropecuario (ICA) (Colombian Agronomy Institute). The agreement between the institutes includes three main features: a multifactorial diagnosis survey, introduction of germplasm and studies on the epidemiology of *Mycosphaerella* diseases.

The diagnosis survey was performed from 1990 to 1992 and gave important results. The current situation in plantain agronomy and health was determined and the limiting factors for production were analyzed. The main aspects of each part of the survey are summarized as follows:

- 'Dominico Hartón' is the variety most commonly cultivated and marketed, followed by 'Dominico' ('French' plantain). These cultivars are almost always mixed in rural holdings.
- The intercropping system with coffee is predominant at 85% with low planting density (less than 300 plantains per ha). There are two planting methods: rows or mats. There are few monoculture zones.
- Plantains are grown for on-farm consumption with occasional sales. Sales are in quantity (bunches) to middlemen.
- Production and productivity are very low (2 to 3 tonnes per ha per year) because of the low planting density and lack of maintenance. However, production potential is very high.
- Agronomic practices are limited: a technological "package" called "arreglo" with simultaneous leaf removal, felling and weeding is applied two or three times a year. Fertilization is carried out occasion-

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[1] *Renamed CIRAD-FLHOR in March 1993.*