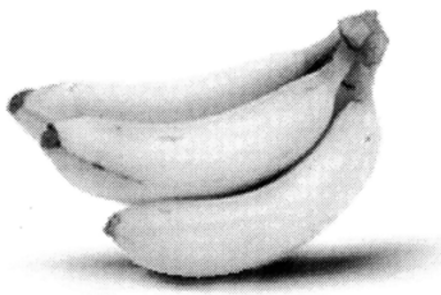 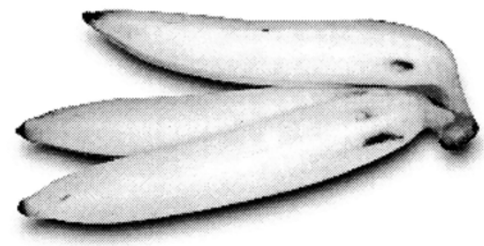

BANANA AND PLANTAIN PROGRAM

TECHNICAL REPORT - 1998

CONTENTS

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Banana and Plantain Program, Honduran Foundation for Agricultural Research, La Lima, Cortés, Honduras

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Abstract: **The exceptional plant and fruit characteristics of the FHIA-25 cooking banana were verified this year. This is the first triploid hybrid which has been developed from 4x x 2x crosses. It is a dwarf, productive, black Sigatoka-resistant plant and its green fruit has an excellent texture and flavor when boiled or fried. It is anticipated that this hybrid will greatly alleviate the food shortages for about 100 million people in Africa where black Sigatoka has drastically reduced the yields of plantains and cooking bananas.**

It was shown that tetraploid hybrids derived from Lowgate (Gros Michel dwarf mutant) have the desired Grand Nain-type plant height in breeding for new disease-resistant export bananas.

An apparent dwarf mutant of the FHIA-20 plantain hybrid was identified. This plant will be multiplied by tissue culture to determine if this more desirable plant height is expressed in a larger number of plants.

The first hybrids from tetraploid x tetraploid hybrids to improve cooking bananas and plantains were selected. The objectives of these crosses are to incorporate resistance to the banana weevil in cooking bananas and to develop dwarf plantains with the plant vigor of the ABB clones.

A hybrid was selected from crosses onto the Pisang awak clone. Pisang awak is a favored beer banana in East Africa and an important dessert and cooking banana in Asia, but is susceptible to Fusarium wilt. If this new hybrid has the disease resistance of its SH-3437 diploid parent, it could be a valuable replacement for Pisang awak in several countries.

Introduction: According to the official figures of the FAO, about 800 million people suffer daily from hunger and the majority of these people live in the tropics. These food shortage problems are perpetuated in part by the uncertainties associated with production of grain crops. Droughts, diseases, insects, lack of adequate storage facilities, and unsuitability for cultivation in home gardens contribute to an almost continuous insufficiency of the basic grains in many tropical countries.

Plantains and cooking bananas had historically largely escaped these problems related to the production of the various grains. However, the black Sigatoka leaf spot disease (*Mycosphaerella fijiensis*), which spread to most banana- and plantain- producing countries in the 1980s, is now causing up to 50% yield reductions on these previously secure domestic food crops. As a consequence of the current, much-reduced availability and higher prices because of scarcity, the plantains which had been a traditional staple food for 70-80 million people in West and Central Africa are now a luxury for many of these millions. Black Sigatoka is presently beginning to have the same effect on the cooking bananas in East Africa where these starchy bananas are the main food for 20 million people. Thus, this disease is causing serious hardships in what was a food-deficient continent even before these relatively recent epidemics.

A scientific breakthrough which could be very instrumental in alleviating these food shortages would be the development of a hardy, productive, black Sigatoka-resistant cooking banana. Then, immediate relief from much of this hunger would be forthcoming as quickly as such a cooking banana could be distributed around the tropical world by the agencies with mandates for attending to food security needs.

The highlight of this annual report is the FHIA-25 cooking banana hybrid, which was first selected as a single plant in 1997. Further observations of several plants of FHIA-25 in 1998 have shown that it is an exceptional candidate for the widespread distribution proposed in the preceding paragraph.

This development of FHIA-25 is an achievement of such apparent significance that it could be used as the example which, in retrospect, has justified many times over the efforts and expenses during almost 40 years of breeding activities. It is the first bred triploid which has excellent plant and bunch features. Indeed, the series of cross-pollinations which resulted in FHIA-25 are indicative that the same type crosses (for the production of secondary and tertiary triploid hybrids) could now be expected to be effective for development of black Sigatoka-resistant export bananas.

Additional information about FHIA-25 is discussed and illustrated under the section about breeding cooking bananas. The advancements made during 1998 in breeding dessert bananas, plantains, and beer bananas are also presented under the appropriate headings.

Breeding dessert bananas

The earlier discoveries in dessert banana breeding have resulted in the established guidelines for approaches to the genetic improvement of all the different types of bananas and plantains. A review of the priorities and principles which led to the development of the several hybrids which are currently being cultivated commercially is provided here as background information.

All progress in *Musa* breeding is dependent upon the availability of genetically-improved diploids. These diploids are crossed onto seed-fertile triploids for the synthesis of tetraploid hybrids, and the desirable features of these tetraploids are directly proportional to the qualities of the diploid parental lines. Thus, the development of diploids which have combinations of superior agronomic features and resistances to pests and diseases has always been the top priority. The best tetraploids from these 3x x 2x crosses are selected as potential new commercial hybrids or as parental lines in subsequent 4x x 2x crosses to produce secondary triploid hybrids for further evaluations and selections.

The second most important breeding principle, once the parental lines for a cross-pollination with a particular objective have been chosen, is to produce and plant out as many segregating progenies as is merited. The more heterozygous the parental lines, the larger the segregating populations should be in order to reasonably expect that an individual segregant with the anticipated desired characteristics will subsequently be identified and selected.

The above information concerning breeding strategies illustrates that the present scope of activities should be greatly enlarged for more rapid attainment of specific objectives. One of these objectives is the development of a black Sigatoka-resistant replacement for the highly susceptible Cavendish export banana. This disease has the potential to destroy this annual $5 billion industry if it evolves (by mutation or genetic recombination) into a strain uncontrollable with approved fungicides.

In breeding for disease-resistant, export-type, dessert bananas, the Highgate dwarf mutant of Gros Michel has been the triploid female parental line for many years. As reported last year, the FHIA-23 tetraploid, which was derived from Highgate x SH-3362, is now being grown commercially in Cuba because of its tolerance to black Sigatoka and its excellent fruit quality (when ripened naturally without ethylene treatment). This is the first time that a bred hybrid has been favored over Cavendish as a dessert banana for commercial plantings, and the current 1,900 hectares of FHIA-23 in Cuba are being expanded as rapidly as additional planting material can be produced.

However, one drawback of FHIA-23, and of all hybrids derived from Highgate, is a plant height at least one meter taller than that of the standard Grand Nain export variety. For this reason, the Lowgate shortest dwarf mutant of Gros Michel is now the predominant triploid parental line in the current 3x x 2x crosses to produce commercial-type tetraploid hybrids.

This year, three tetraploids derived from Lowgate x SH-3362 were evaluated in the field. All these hybrids have the ideal Lowgate-like short plant height (Fig. 1), but they are susceptible to black Sigatoka and have mediocre bunch features. The breeding principles outlined earlier help to explain why the FHIA-23 tetraploid with Highgate parentage has such desirable qualities that it is being grown commercially, but these three hybrids with Lowgate parentage do not have disease resistance and bunch features which would make them candidates for commercial cultivation.

Highgate is much more seed-fertile than Lowgate, and relatively large populations of tetraploid hybrids are readily obtained from crosses onto this taller of these two dwarf mutants of Gros Michel. As a consequence, FHIA-23 was selected from among more than 100 segregating hybrids derived from Highgate x SH-3362. Since SH-3362 is highly heterozygous, this rather large population provided possibilities for the best recombinations of desirable genes from this diploid with those of Highgate.

In contrast to the one or more seeds produced per hand-pollinated bunch of Highgate, an average of about one seed is obtained per 60 pollinated bunches of Lowgate. Thus, the very limited segregating population (three plants) from these Lowgate x SH-3362 crosses did not fully permit the potential for expression of the desirable genes of SH-3362 in any of these tetraploids.

Plant breeding is very much an art and science of projection based on astute analyses of what has been learned in prior endeavors. For example, Dodds, a pioneer banana breeder in Trinidad, concluded more than 50 years ago that commercial tetraploids would be forthcoming as soon as advanced bred diploids were developed. This conclusion proved to be right, as is demonstrated with the current tetraploids which are being cultivated in many countries. Now, FHIA-23 shows that a hybrid with excellent bunch qualities and tolerance to black Sigatoka is obtainable, and the three hybrids with Lowgate parentage which were evaluated this year demonstrate that tetraploids with the desired dwarf plant height can also be produced. The development of a new commercial hybrid like FHIA-23, but with a Grand Nain-type plant height, is just a matter of pollinating the thousands of bunches of Lowgate necessary to provide large populations of segregating hybrids from which to make selections.

More than 20 years ago, it was learned that triploids derived from crossing diploids onto tetraploids with Highgate parentage frequently have a shorter plant height than Highgate. However, these earlier triploids did not have good bunch features. Two things have happened to indicate that these 4x x 2x crosses should be resumed. One is that much better diploids are now available for these crosses. The other is the development of the FHIA-25 tertiary triploid cooking banana hybrid which involved 4x x 2x crosses. Not only does FHIA-25 have exceptional plant and bunch features, it also is highly resistant to black Sigatoka. This very high level of resistance to this disease is attributed to the fact that additional resistant diploids were introduced into the pedigree of this bred triploid. Thus, it can now be expected that triploids from 4x x 2x crosses in breeding for new dessert bananas will also have higher levels of black Sigatoka resistance than the tetraploids derived from 3x x 2x crosses in this breeding objective.

This year, about 600 bunches of the SH-3444 (FHIA-23) tetraploid were pollinated in these 4x x 2x crosses. A total of 84 seeds were obtained, of which 20 had embryos which were cultured for germination. Two of the 17 plantlets which resulted from germination of these embryos have the gene for dwarfness, and these two plants will soon be transplanted to the field for subsequent evaluation. This breeding scheme should be greatly expanded, and the justification for this amplification is readily evident in the next section which describes the development of the FHIA-25 cooking banana hybrid by way of 4x x 2x crosses.

Fig.1. One of the three tetraploid hybrids derived from Lowgate x SH-3362 which flowered this year. This plant illustrates the desirable short plant height of tetraploids with Lowgate parentage.

Breeding cooking bananas

So far, this has been the most challenging and most rewarding of all the breeding endeavors. The challenge arose from the fact that, unlike in breeding for new dessert bananas and plantains, there was no known natural, dwarf, triploid parental line which could be used in 3x x 2x crosses for the genetic improvement of cooking bananas. The bred SH-3386 dwarf triploid became and remains the only fixed female parental line which has proven to be useful in this breeding objective. However, the reward has been that a subsequent selected hybrid, SH-3775, with SH-3386 ancestry (by way of the SH-3648 tetraploid which was derived from SH-3386 x SH-3362) is now an exceptional new triploid cooking banana.

The SH-3648 x SH-3142 pedigree of SH-3775 was described last year when this new triploid was first selected among 175 segregating hybrids from this 4x x 2x cross. SH-3775 has now been named FHIA-25, and it is the first commercial-type triploid to be developed in the FHIA program. Several FHIA-25 plants produced fruit this year, and the outstanding features of this hybrid were confirmed in this increased number of plants for evaluation. As a result of this confirmation, FHIA-25 is now considered to be an excellent candidate for extensive trials in all countries where boiled or fried green bananas and plantains are important foods.

A representative plant of the dwarf FHIA-25 with a bunch ready for harvest is shown (Fig. 2). This robust plant readily supported this 43.0 kg bunch without the need for propping. FHIA-25 has a very high level of resistance to black Sigatoka, and is tolerant to extreme stress from environmental conditions. For example, hurricane Mitch caused flooding four feet deep during 4 days in the plot where the FHIA-25 plants are located. The leaves of all the surrounding plants of other hybrids and varieties turned yellow because of these adverse conditions, but the leaves of FHIA-25 remained green as if nothing had happened.

It is now apparent that FHIA-25 could become a very valuable replacement for plantains in West and Central Africa, where black Sigatoka has greatly reduced the availability of this formerly staple food for 70-80 million people. In the 1997 report, a comparison was shown between the small bunch size of Yangambi and the large bunch size of FHIA-25. The black Sigatoka-resistant Yangambi has been planted as an alternative to plantains in several areas of Nigeria as a matter of survival. Now, the black Sigatoka-resistant Cardaba ABB cooking banana is also being evaluated in that country as a partial solution to the critical food shortages brought about by this disease. Relative bunch sizes of Cardaba and FHIA-25 are shown (Fig. 3). In addition to having a bunch about twice as large as Cardaba, FHIA-25 also has a superior fruit quality. Boiled green fruit of Cardaba is very dense and has a hard texture, while that of FHIA-25 has a more desirable softer texture. In Honduras, the consensus of opinion by those who have tried FHIA-25, both boiled and fried as chips, is that this new hybrid would be a very adequate replacement for plantains eaten as green fruit.

Harvested fruit of FHIA-25 has a relatively long green life, so it could be grown by farmers for marketing. For family gardens, the short plant height would facilitate harvesting the fruit a hand at a time as needed from hanging bunches. This sequential partial harvesting technique (Fig. 4) would prolong the availability of green fruit from the same bunch over a 6-week period.

FHIA-25 could also be a valuable replacement for the East African AAA highland cooking bananas which are the main food for 20 million people in Uganda, Rwanda, Burundi, and the higher altitude regions of Tanzania and Democratic Republic of Congo. These highland banana clones, which are cultivated only in this area of Africa, are highly susceptible to black Sigatoka and this disease is now causing severe yield reductions in these five countries.

This year, tissue-cultured plantlets of FHIA-25 were sent to Australia, Cuba, Ghana, Haiti, Jamaica, Malaysia, Nepal, Nigeria, Papua New Guinea, Peru, South Africa, St. Croix, Tanzania, Uganda, and Democratic Republic of Congo. Currently, this hybrid is being multiplied for distribution in several different regions of Honduras.

FHIA-25 has a bland flavor when ripe, so it is recommended only as a green cooking banana. This absence of a good ripe flavor does not affect its green fruit qualities, but a dual purpose (cooking and dessert) banana would be even better. In this regard, it has already been found that FHIA-25 is seed-fertile when pollinated with pollen from diploids. This seed fertility does not present a problem of potential seediness when FHIA-25 is grown commercially since it is a triploid and would not be self-fertile. However, this fertility as a female parent permits the use of FHIA-25 in 3x x 2x crosses in further breeding endeavors. If the pending progenies from these crosses are tetraploids, it will offer possibilities for subsequent selection of new cooking banana hybrids which will have the exceptional plant and green fruit qualities of FHIA-25 and also have a good ripe fruit flavor.

As in the case of breeding dessert bananas, the activities in breeding cooking bananas should also be greatly increased to permit making the numbers of crosses merited by the positive results obtained and the needs. For example, FHIA-25 has excellent resistance to black Sigatoka, but its reaction to the banana weevil is not yet known. This weevil is a very serious production constraint in most places where cooking bananas are grown.

It has been observed that Gros Michel is resistant to the banana weevil in areas where the East African cooking bananas are severely infested with this insect. Thus, the possibility exists for incorporating these genes for resistance into new cooking bananas. This year, the SH-3779 tetraploid hybrid was selected from a 4x x 4x segregating population derived from SH-3648 x SH-3444. SH-3648 is the dwarf tetraploid parent of FHIA-25, and SH-3444 has Gros Michel genes by way of Highgate x SH-3362. Bunch characteristics of SH-3779 and its two tetraploid parental lines are illustrated (Fig. 5).

This SH-3779 secondary tetraploid is a dwarf plant and has a high level of resistance to black Sigatoka. In addition to the possibility that this new hybrid will have genes for resistance to the banana weevil, it could also have genes for a good ripe flavor in a cooking banana. The planned next step is to cross advanced diploids onto SH-3779 to produce triploid hybrids for evaluation as possible new dwarf, black Sigatoka-resistant cooking bananas which are also resistant to the banana weevil and have a good flavor, when ripe.

Fig. 2. Illustration of the dwarf plant stature of the FHIA-25 cooking banana hybrid. The bunch shown weighed 43.0 kg and the plant readily supported this large bunch without the need for propping.

Fig. 3. Relative bunch sizes of the Cardaba ABB cooking banana clone (left) and FHIA-25. The black Sigatoka-resistant Cardaba is being evaluated in Nigeria as a possible substitute for the traditional plantains which have been devastated by this disease. FHIA-25 is also resistant to black Sigatoka, and, in addition to its much larger bunch, its green fruit has a more desirable (softer) texture than that of this ABB clone when cooked. In Honduras, consumers have rated green FHIA-25 fruit as an acceptable replacement for plantains when boiled or fried as chips.

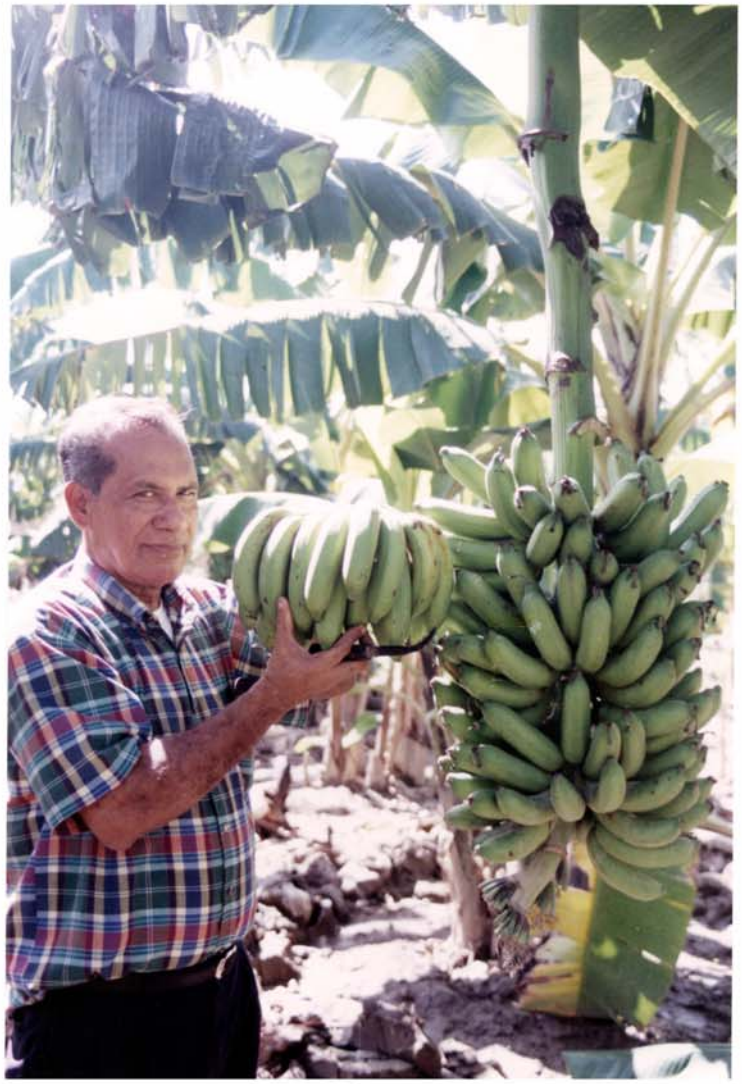

Fig.4. Illustration of the recommended way to harvest FHIA-25 fruit in home gardens. This sequential removal of fruit as needed from hanging bunches would prolong the availability of green fruit from the same bunch over a 6-week period. The harvested hand shown is the sixth hand on this 14-hand bunch from which two hands were harvested weekly.

Fig.5. From left: Bunch characteristics of the tetraploid SH-3648 (with ABB ancestry) and SH-3444 (Gros Michel-type) parental lines, and the SH-3779 progeny. This 4x x 4x cross was made in an attempt to incorporate the resistance to the banana weevil of Gros Michel into cooking banana hybrids. SH-3779 is a vigorous dwarf plant with a high level of resistance to black Sigatoka. The next planned step is to cross advanced diploids onto SH-3779 to produce triploid hybrids for evaluation as potential new cooking bananas with resistance to the banana weevil.

Breeding plantains

The FHIA-20 plantain-type hybrid was described last year, and it is illustrated again here (Fig. 6) to emphasize once again the contributions of plant breeding for improving this staple food for more than 100 million people. FHIA-20 shows that productive, black Sigatoka-resistant plantains can be bred, and is indicative that even better hybrids could be expected to be forthcoming from expanding the crosses made in this breeding objective.

Dwarf mutant of FHIA-20 plantain

The universally cultivated False Horn plantain is a tall plant, and the FHIA-20 and FHIA-21 plantain hybrids which are now being cultivated commercially are also tall. It was anticipated that dwarf mutants of FHIA-20 and FHIA-21 would be identified among the several thousand plants of these two hybrids which have been multiplied by micropropagation. So far, no dwarf mutant of FHIA-21 has been observed, but an apparent semi-dwarf mutant was found this year in a plot of FHIA-20. This plant, named FHIA-20D (for FHIA-20 dwarf), is shown (Fig. 7). Unfortunately, hurricane Mitch toppled the plant with the bunch shown before it matured, but the suckers of this plant survived. FHIA-20D will be multiplied by tissue culture to determine if plants from this apparent mutant mother plant maintain this more desirable shorter plant height.

Backcrossing to improve tetraploid plantain hybrids

In addition to having small bunches and being susceptible to black Sigatoka, plantains are lacking in plant hardiness. As compared with the robust ABB cooking bananas, the AAB plantains are relatively non-vigorous. Now, there is a possibility of breeding plantains with the vigor of the ABB clones by way of 4x x 4x crosses. This year, the SH-3778 hybrid was selected from among segregating populations derived from crosses between the dwarf SH-3688 tetraploid (with ABB ancestry) and the FHIA-21 plantain. Bunch characteristics of these two parental lines and the SH-3778 progeny are shown (Fig. 8).

SH-3778 is a vigorous dwarf plant and has a high level of resistance to black Sigatoka. The next step in this crossing scheme is to backcross FHIA-21 onto SH-3778. It is not known what the outcome of these 4x x 4x crosses will be, but the importance of plantains readily justifies undertaking this approach for the development of productive, dwarf, vigorous, black Sigatoka-resistant plantain-type hybrids. Backcrossing is a widely used breeding strategy in the genetic improvement of most crops, and this is the first time that backcrossing has been employed in the improvement of tetraploid plantain hybrids. This series of crosses should be pursued on a much expanded scale.

Fig.6. A representative 9.0 kg bunch of the traditional False Horn plantain (center) as compared to two 33.0 kg bunches of the black Sigatoka-resistant FHIA-20 plantain hybrid. Both FHIA-20 bunches were pruned to leave only five hands (bunch on left) and six hands (bunch on right) for subsequent development after bunch emergence. Bunches of FHIA-20 produce up to 11 hands, and early removal of some of these hands promotes the development of longer and fuller fingers in the remnant hands.

Fig.7. An apparent semi-dwarf mutant of the tall FHIA-20 plantain hybrid. This plant, named FHIA-20D (for FHIA-20 dwarf) will be multiplied by tissue culture for further evaluation of the stability of this shorter plant height.

Fig.8. From left: Bunch characteristics of the tetraploid SH-3688 (with ABB ancestry) and FHIA-21 (plantain-type) parental lines, and the SH-3778 progeny. This 4x x 4x cross was made in an attempt to combine the vigor of ABB clones with the eating qualities of plantains. SH-3778 is a vigorous dwarf plant with a high level of resistance to black Sigatoka. The next step is to backcross FHIA-21 onto SH-3778.

Breeding beer bananas

Pisang awak (ABB) is cultivated extensively in all the East African countries for making beer (about 400,000 hectares of bananas are grown for this purpose in Uganda alone). The popularity of Pisang awak is due to its hardiness, its resistance to leaf spot diseases, and its fruit qualities. The weaknesses of this clone are that it is a tall plant and it is susceptible to Panama disease.

From the few hybrids which have been obtained from crossing diploids onto Pisang awak, it now appears that both of these weaknesses can be overcome by breeding. Bunch features of the SH-3776 hybrid and its Pisang awak and SH-3437 parental lines are shown (Fig. 9). While this first bunch of SH-3776 is not as large as typical Pisang awak bunches, the bunch and finger shapes of this hybrid and its maternal parent are almost identical. More important still than this similarity of external features, the pulp color (cream-colored) and ripe taste of this hybrid are almost identical to those of Pisang awak.

It is not yet known if SH-3776 has the Panama disease resistance of its SH-3437 diploid parental line, but there is a good possibility that it does. What is known is that this hybrid is very vigorous, is highly resistant to black Sigatoka, and is fast to shoot and ratoon. Based on the conditions under which it was grown, it is expected that subsequent bunch sizes of SH-3776 will be larger. Of special significance is the fact that SH-3776 does not produce pollen. This absence of pollen is unusual for tetraploids derived from 3x x 2x crosses, but is a desirable trait since it means that this hybrid could be cultivated without problems with seeds in the fruit.

When Dr. R. H. Stover made a survey of pests and diseases in East Africa in 1987, he found that Pisang awak was free of banana weevil damage in areas where other varieties were susceptible. This indicates that tetraploids derived from Pisang awak could possibly serve as a source of resistance to this insect in 4x x 4x crosses with tetraploids derived from other triploids (e.g., Highgate, the French plantains, and the ABB clones). Gros Michel also has shown resistance to the banana weevil, but otherwise the only known source of resistance is Yangambi. So far, using Yangambi as a parental line in crosses has not resulted in any hybrids with acceptable plant and bunch features. The possibilities for expanding the genetic make-up of potentially valuable hybrids through 4x x 4x crosses are almost unlimited, but will have to be restricted for the present because of funding limitations for these activities.

Fig.9. Bunch features of the Pisang awak triploid (left) and SH-3437 diploid (middle) parental lines as compared to those of the SH-3776 tetraploid hybrid. Pisang awak is being destroyed by Panama disease in several East African countries where it is a favored beer banana. The purpose of crosses onto Pisang awak is to develop hybrids with all the desirable traits of this clone in combination with resistance to this disease.

Present situation

After 1984, when United Brands Company unconditionally donated its very advanced banana breeding program to FHIA, this program became an extremely valuable gift to the world of banana and plantain producers and consumers.

With short-term funding assistance from many different donor agencies during 1984-1998, several disease-resistant hybrids of the diverse types of bananas and plantains were developed. These hybrids are now being cultivated on several thousand hectares and in many countries.

As of January, 1999, the only funding for the continued activities in this program is from a very limited FHIA endowment fund. Thus, without additional outside funding, the large scale crosses and selections needed (as described in this report) cannot be done.

This report was written very much as an appeal to donor agencies with mandates for attending food security needs. Some of the most critical of these needs were outlined in the introduction of this report. It is safe to say that, without the accomplishments in banana and plantain breeding, there would be little hope for practical solutions to the current disease problems on these major food crops.

There have been few, if any, such proven possibilities for alleviating the hunger and hardships of so many people with such a small investment. Indeed, the time and expense required to show that bananas and plantains can be improved by breeding, the same way that most other crops have been improved, have already been borne by the farsighted pioneers who foresaw the eventual need for disease-resistant hybrids. Now, no center has to be built. No administrative facilities have to be put in place to handle payrolls, insurance, etc. All that is required is funding for the continued activities as explained in this report. The anticipated direct beneficiaries from the results (improved hybrids) of this funding would be far more than 100 million people.