PROMUSA

A Global Programme for *Musa* Improvement

A banana breeder's response to "The Global Programme for *Musa* Improvement (PRO*MUSA*)", article published by the CGIAR

Figure 1. *FHIA-21 on sale in supermarket in San Pedro Sula, Honduras*

The above PRO*MUSA* article was published by the CGIAR in 1997 in the *Issues in Agriculture 12* booklet titled "Global Programs: A New Vision in Agricultural Research". The senior author is the Director of INIBAP. Since May 1994, INIBAP has been under IPGRI as a member of the CGIAR international centers, and INIBAP is responsible for providing the executive secretariat to PRO*MUSA*.

The stated mission of INIBAP is to increase the productivity and stability of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

The authors do a very good job of describing the serious disease and pest problems on bananas and plantains worldwide, and they are right when they say that development of disease-resistant hybrids is the most critical need. I have always wondered why the CGIAR did not express more interest in banana and plantain breeding, and it is encouraging to see that this is now happening.

Since it is not possible to cover all aspects of *Musa* improvement in a short article like PRO*MUSA*, hopefully this response is not out of order. Actually, a better description than response would be "additional viewpoints". I know that the CGIAR frequently invites outside opinions, and I thought that some of my observations during 28 years as a banana and plantain breeder could be helpful.

In examining the sentiments expressed below, I trust that the reader will keep the vital importance of the subject in mind. Far more than 100,000,000 people stand to be directly affected by the decisions concerning allocations of funds for the development of new disease-resistant banana and plantain hybrids. Thus, it is critical that the right decisions be made.

The inadvisability of starting new breeding programmes

In my opinion, it would not be advisable to consider starting additional new breeding programmes. The reason for this is that the approaches to genetic improvement of *Musa* are quite complicated as compared to those of most crops.

There is one key step in the *Musa* breeding process that is of the utmost importance since all progress in genetic improvement is dependent upon it. This key step is the development of agronomically-improved, disease-resistant diploid parental lines. These improved

PRO*MUSA*News

2nd Global meeting

INIBAP is presently organising the second global PRO*MUSA* meeting. This meeting is due to be held in Cameroon in November 1998 and will be held in association with a meeting of the Principal Investigators of the World Bank/FAO/CFC Banana Improvement Project, just before the International Symposium on Bananas and Food Security. Two days (tentatively November 8 - 9) have been set aside for the PRO*MUSA* meeting. It is anticipated that separate meetings of most of the working groups of PRO*MUSA* will also be held during this meeting.

BSV meeting

Within the framework of the Virology working group, a meeting focusing on BSV was organized by INIBAP and held in Montpellier from 19-21 January, 1998. The meeting brought together the most prominent virologists working on BSV for three days of discussions and exchange of information and ideas. The meeting focused on recent advances in the understanding of the virus and the significance of integrated viral sequences in the *Musa* genome. Research needs were analysed and prioritized and current BSV indexing procedures reassessed in the light of research results. It was generally agreed that the current indexing methods are still the most reliable for detecting a wide range of BSV isolates, and revisions to the Technical Guidelines for the Safe Movement of *Musa* germplasm were not considered necessary. The proceedings of the meeting will be published shortly by INIBAP.

Genetic Improvement Working Group

In relation to the development of molecular markers in *Musa* as a means of improving breeding efficiency, an agreement has been signed between CORBANA and INIBAP to establish a number of segregating populations. These populations will be used in the identification of molecular markers for specific traits and the plants produced would be made available to research laboratories for molecular marker research.

The project, which started in mid-December 1997, will run for a period of three years and four months and will be supervised by Dr Jorge Sandoval of CORBANA.

Initial crosses will be made by EMBRAPA, Brazil to generate one or two segregating populations which will complement populations available at other institutions. The populations will be established at CORBANA bred diploids are subsequently used as the male parents in cross-pollinations onto seed-fertile triploids for the synthesis of tetraploid hybrids. (A publication which describes the advances made in diploid breeding in the FHIA programme is: Rowe P.R. and F.E. Rosales. 1996. *Bananas and plantains* pp. 167-211 *in* J. Janick and J. N. Moore (eds.). Fruit Breeding, Vol. I: Tree and Tropical Fruits. John Wiley & Sons, New York).

An investment of several million dollars and almost 40 years of exhaustive cross-pollinations and selections were required to develop the genetically-improved diploids in the FHIA programme. Some of these advanced diploids have already been used as male parents in the development of several disease-resistant tetraploid hybrids now being cultivated commercially on several thousand hectares.

It would be practically impossible to duplicate these accomplishments in new diploid breeding schemes. All the natural diploids which were collected in Asia and are in germplasm collections (and FHIA's field collection is still the largest in the world) have very inferior features which include absence of edible pulp, male or female sterility, unacceptable flavors, and agronomically inferior (small) bunches. The unparalleled accomplishment of my predecessor, Dr D.L. Richardson, was the development of a bred diploid, SH-2095, which has outstanding bunch features (very large bunch with long and parthenocarpic fruits). It took 10 years (1959-69) with the aid of an average of four professional assistants, about 90 laborers, and the evaluations of up to 10,000 diploid hybrid plants annually to develop and select SH-2095.

Now, SH-2095 is in the pedigree of practically all the current improved, disease-resistant diploids in the FHIA programme. A good, and fair, question at this point would be, "Just how valuable have these advanced bred diploids been?".

To illustrate this value, let us look at the black Sigatoka-resistant FHIA-21 plantain hybrid which was developed by using one of these bred diploids in cross-pollinations onto a seed-fertile plantain. This FHIA-21 plantain hybrid is now being grown commercially in Honduras and several other Latin American countries. While this reference to the cultivation of FHIA-21 is confined to Latin America, there is now a scarcity of plantains in practically all producing countries worldwide. This scarcity is because the yield of the universally-cultivated False Horn plantain has been reduced by up to 50% as a result of defoliation by black Sigatoka during the last 20 years.

For this illustration, I went to three supermarkets in San Pedro Sula, the second largest city in Honduras, in search of plantains. The first supermarket had only False Horn plantain on sale. These were of poor quality and cost US$0.92 for ten fingers. FHIA-21 was the only plantain available at the second supermarket (Figure 1). The fruit were larger than False Horn (ten fingers weighed 50% more) and the cost was US$1.06 for ten fingers. The third supermarket had no plantains in stock at all. So, for a US$0.14 higher price for the same number of fingers, the consumer receives 50% more edible fruit with FHIA-21. The consumer benefits by buying FHIA-21, but the farmer benefits even more. In all trials comparing FHIA-21 with False Horn, FHIA-21 has been more than twice as productive than this traditional plantain in Honduras.

A realistic appreciation of how difficult it has been to develop improved diploids can be gained by reviewing the published reports of all other breeding programmes which have been established in the last 20 years. The most frequently mentioned diploids used in these breeding schemes are Calcutta 4 and Pisang Lilin, which are resistant to black Sigatoka, but have very small bunches. These inferior bunch sizes are expressed in the tetraploids derived from these two diploids. This is in no way intended as an unkind remark about these programmes; however, it is intended to show just how extremely difficult, expensive, and time consuming this diploid improvement scheme has been and is.

The dwarf wheat varieties (which are rightfully credited with saving millions of lives and for which Dr Norman Borlaug was awarded the Nobel Peace Prize in 1970 for his work in developing them) and the maize streak virus-resistant maize varieties (that greatly increased the production of this major food crop in Africa) are two of the outstanding accomplishments of strong, concentrated efforts in international centers sponsored by the CGIAR. Bananas and plantains are even more important than wheat and corn as domestic food crops in many areas of the world. A strong *Musa* improvement programme would be much more effective than several small programmes for meeting the needs of banana and plantain farmers and consumers.

Plant breeding vs. biotechnology

In my opinion, the PRO*MUSA* article gives more credit to biotechnology and genetic engineering than has actually been earned. It is not recent developments in biotechnology which have allowed some of the barriers to genetic improvement in *Musa* to be overcome. The development of agronomically-improved, disease-resistant diploid breeding lines is what has led to surmounting these barriers — just as, more than 50 years ago, Dodds in Trinidad correctly predicted that it would be (Dodds K.S. 1943. *The genetic system of banana varieties in relation to banana breeding*. Empir. J. Exp. Agric. 11: 89-98).

The *Summary of Proceedings and Decisions* of the 27-31 October 1997 International Centers Week in Washington, D.C. has some interesting comments about biotechnology. In one place (p. 26), it is said that developments in biotechnology "raise important concerns for the CGIAR, but also present exciting opportunities to accelerate germplasm enhancement via a more strategic research effort". On another page (p. 7), it is said that, "In Cairo, when we discussed the promise and perils of biotechnology, we agreed that these questions must be scrutinized in light of reason, in the presence of evidence, and not governed by emotion or prejudice".

I am in complete agreement with this latter statement by the CGIAR. "In light of reason", a

and, assuming good segregation is obtained, will be evaluated for parthenocarpy, bunch orientation, resistance to black Sigatoka, *Radopholus similis* and agronomic traits. Fusarium wilt evaluation depends on the availability of suitably infested land and will not be part of this project at present.

Nematology Working Group

The participants in the nematology working group have been particularly active in developing ideas for collaborative projects and these will be discussed further at the Cameroon meeting. Ms. Inge Van den Bergh, the INIBAP/VVOB Research Associate recently appointed to work with VASI in Vietnam has started evaluating Vietnamese germplasm for nematode resistance. Within the framework of this working group, another VVOB Research Associate, Thomas Moens, has recently been appointed to work at CORBANA. He will be assisting with the evaluation for nematode resistance of the segregating populations established within the framework of the Genetic improvement working group.

Fusarium Working Group

Within the framework of the Fusarium wilt working group, 11 countries have sent samples from wilted plants to QDPI, Australia for isolation and analysis of *Fusarium oxysporum* f.sp. *cubense* (Foc). Vegetative compatibility group (VCG) and volatile production analysis have been completed, while molecular analysis (RAPD-PCR and DAF) are still ongoing for those samples where VCG's could not be determined, or which had unusual morphology and atypical volatile production. The results of the analysis provide information on the global diversity of *Foc* and are available from INIBAP (Annual report, 1997). One sample from India contained Tropical Race 4 (VCG 01213/16), the first report of this race of Fusarium in India.

Global and regional evaluation programme

The majority of the IMTP Phase II evaluation sites have now completed the evaluation work and the first results have been received by the programme coordinator. The global analysis of the data has already started. Initial results indicate that the FHIA hybrids are performing well across a range of environments and disease pressures. A first version of the IMTP candidate clone database has been completed and available data is being entered. The database will eventually contain information on pest/disease resistance/-tolerance and agronomic performance under specified conditions of improved hybrids and other cultivars available for evaluation by NARS.

A number of breeding programmes, including CIRAD, FHIA, IITA and CRBP, have agreed to contribute improved hybrids for testing in the next phase of IMTP. Most of these hybrids have already been received by the ITC and are presently undergoing virus indexing prior to distribution for evaluation.

New structure for IMTP

The International *Musa* Testing Programme is now operating within the framework of PRO*MUSA*. The structure of the programme has therefore been revised to better serve the germplasm evaluation needs of programme participants. The revised structure also takes into account the needs of the growing number of national programmes wishing to participate in the programme.

The main feature of the revised programme is the introduction of two levels of evaluation:

- **In-depth evaluation:** Evaluations that are carried out at the in-depth sites are detailed and will include not only disease and pest resistance/tolerance screening but can also be combined with epidemiological studies on pathogen populations, studies on host-pathogen relationships for different races of the pathogen and adaptability and yield studies. The evaluation protocols used at these sites are elaborate, requiring time and expertise. The information obtained is primarily useful to breeders and pathologists.
- **Performance evaluations:** The majority of evaluation sites will carry out performance evaluations, where the material is assessed for disease resistance, agronomic adaptation and stability using a simple protocol requiring a minimum of time and expertise. Collaborators at these sites can select the clones they wish to evaluate based on information provided by INIBAP, according to local needs and conditions. The information obtained is primarily useful to extension agents and farmers.

Revised protocols for the two levels of evaluation have been developed by the Fusarium and Sigatoka working groups and are being published by INIBAP. Both types of evaluation sites provide feedback information on the agronomy, pathology and adaptation of improved varieties to INIBAP. This information is compiled in a database, which will be linked the *Musa* Germplasm Improvement System (MGIS) database. Information is then fed back to the breeding programmes and is also available for other NARS to assist in their choice of appropriate, well characterised varieties for testing.

If you would like to receive more information about the IMTP, or are interested in participating in the programme, please contact the IMTP Coordinator at INIBAP Headquarters, Montpellier France.

review of what led to the historical development of almost 100% of the productive and disease-resistant varieties of practically all food and fiber crops would reveal that these developments were the results of applications of sound breeding principles by plant breeders. When biotechnology applications have been made, these applications have been almost exclusively to modify plants that had first been improved by plant breeders.

Bananas and plantains have lagged behind most other crops in regard to their genetic improvement for two reasons. The first and primary reason is that, until it was proven possible, very few people believed that it could be done. After all, the varieties which have traditionally been cultivated are natural (non-bred) triploid plants with seedless fruit. The other reason is that, as has been discussed, the development of improved banana and plantain hybrids was dependent upon first developing the necessary diploid parental lines. In spite of the very capable work of numerous dedicated scientists, this development of these advanced diploids took several decades because of the inferiority of the natural diploids which were available for beginning this diploid improvement breeding scheme.

The "presence of evidence" as cautioned by the CGIAR about biotechnology, will be discussed further in the succeeding paragraphs. As has been seen with the discussions about the FHIA-21 plantain hybrid, the "presence of evidence of the value of what is now called conventional plant breeding" has already been demonstrated once, and it will be confirmed again for both plantains and bananas as these discussions continue.

In an attempt to show that I am trying to be objective, I recognize that there have been a few apparent successes from using biotechnology applications for modifying certain characteristics of some plants. Some examples are: alterations of natural fruit ripening, increasing herbicide resistance (but this has met with a recent notable failure in one crop), increasing insect resistance with the Bt toxin (with sporadic success), and increasing virus resistance by introduction of virus coat protein into the genome of certain plants. Thus, I concede that biotech may have some applications for some traits in some plants. But now, let us return to the discussion of biotech applications for improvement of bananas and plantains.

There are no known biotech techniques for increasing inherent low productivity. However, yield is a very important consideration in the genetic improvement of plantains. In breeding to develop productive, disease-resistant plantains by crossing advanced bred diploids onto a seed-fertile plantain clone, black Sigatoka-resistant plantain hybrids with double the yield of the universally-cultivated False Horn plantain have been developed in the FHIA programme. The already-discussed FHIA-21 plantain hybrid is one of these developments, but, as good as it is, FHIA-21 has a weakness in that the green life of fruit after harvest is relatively short when compared to that of False Horn. This weakness requires that harvested fruit be marketed rather quickly.

By using a different improved diploid male parent in cross-pollinations onto the same seed-fertile plantain that is the female parent of FHIA-21, an additional plantain hybrid, FHIA-20, has been selected which also is twice as productive as False Horn. However, FHIA-20 is superior to FHIA-21 in that the fruit has an excellent long green life after harvest comparable to that of False Horn. Like FHIA-21, FHIA-20 is much more resistant to black Sigatoka than False Horn.

Bunch characteristics of the FHIA-20 plantain hybrid as compared to those of the False Horn plantain, with no chemicals applied to either for control of black Sigatoka, are shown (Figure 2). In addition to its excellent yield, FHIA-20 has exceptional eating qualities, and is considered by many consumers to be superior to False Horn when cooked both green and ripe. This bred plantain hybrid is now being grown commercially in Honduras, and these plantings by farmers are expanding rapidly. There is no way that a new plantain with all the outstanding qualities of FHIA-20 could be developed by using biotech applications.

I know of no biotech "success stories" about the introduction of resistance to a fungal disease or a nematode in any crop. Yet, the main disease and pest problems of bananas, plantains, and cooking bananas are, in order of current relative importance: black Sigatoka (a fungus), the burrowing nematode, and Panama disease (a fungus). In addition, the resistances to black Sigatoka, Panama disease, and the burrowing nematode which have been identified in natural banana clones are controlled by

Figure 2. *Typical bunch characteristics of the universally cultivated False Horn plantain (center) as compared to those of the black Sigatoka-resistant FHIA-20 plantain hybrid (on both sides) in Honduras when no chemicals are applied for control of black Sigatoka*

several genes with an additive effect. Thus, since it would be practically impossible to identify and isolate so many genes, biotech is doubly limited in its applications to disease and pest resistance in bananas and plantains. (An excellent popular-style article about biotechnology regarding its applications to crop improvement is: Simmonds N.W. 1997. *Pie in the sky*. The Planter 73(860): 615-623, November 1997. I would gladly send a copy of this article to interested readers upon request.)

The fact remains that practically all cultivated food and fiber crops have been genetically improved, and these improvements have been made by plant breeders. As shown by FHIA-20 and FHIA-21, which were described above, and the FHIA-23 banana hybrid, bananas and plantains have now joined that list. FHIA-23 is a tetraploid dessert banana which was derived from crossing the SH-3362 bred diploid onto the Highgate dwarf mutant of Gros Michel (Gros Michel was the original and only export banana before it was destroyed by race 1 of Panama disease). This new banana hybrid is resistant to race 1 of Panama disease and tolerant to black Sigatoka. More than anything else, these FHIA-20, FHIA-21, and FHIA-23 commercial hybrids are indicator plants. They show that disease-resistant, productive hybrids of bananas and plantains which are preferred by farmers and consumers can be bred, and are indicative that even better hybrids can now be expected to be forthcoming — if these continued efforts in this successful programme are adequately supported.

As emphasized earlier, and it is of such paramount importance that it merits this additional emphasis, all progress in *Musa* breeding has been dependent upon the development of advanced diploid breeding lines, which serve as the male parents in the pollinations of naturally occurring triploids (the cultivated bananas and plantains are examples of triploids, but not the ones used in breeding because they do not produce seeds). With one exception, diploids are not cultivated for commercial production, and their main value is as sources of disease and pest resistances in breeding programmes. The diploid with the best bunch characteristics of all the many diploids which have been collected in germplasm collection expeditions is Pisang Jari Buaya (PJB). PJB is almost sterile (and has no pollen) for breeding purposes, but has been found to be resistant to race 4 of Panama disease and the burrowing nematode, and tolerant to black Sigatoka. One of the most significant accomplishments in the FHIA programme has been the development of the SH-3362 bred diploid which has PJB in its pedigree (Figure 3). In addition to its outstanding agronomic (large bunch) qualities, SH-3362 is also resistant to races 1 and 4 of Panama disease, and is tolerant to the burrowing nematode and black Sigatoka. SH-3362 has been an extremely valuable parent in further cross-pollinations, both in the development of breeding lines with multiple disease resistance and in the synthesis of the FHIA-23 tetraploid, which was described in the preceding paragraph. Accomplishments like the development of SH-3362 are not possible by gene manipulation with biotechnology techniques.

Figure 3. *Bunch characteristics of two diploids illustrate one of the major accomplishments in the FHIA breeding programme. Pisang Jari Buaya (left) is a natural diploid clone from Asia and SH-3362 (right) is a bred diploid, a direct descendant of Pisang Jaru Buaya by way of cross-pollinations and selections*

The questionable value of molecular markers

An action plan advocated in PRO*MUSA* is the identification of molecular markers. In my opinion, this activity should be given a low priority. Based on my experience, a knowledge of "molecular markers" would not have been useful in the development of any of the advanced breeding lines in the FHIA programme, nor would such markers have aided in the development and selection of the several productive, disease-resistant banana, plantain, and cooking banana hybrids now being grown commercially.

In my career as a plant breeder, I have had the good fortune of knowing about 25 very successful breeders of different crops and being exposed to their approaches to genetic improvement. I do not know of an example in which molecular markers would have been useful to these plant breeders in their development of varieties which became the standards of excellence for their chosen crops.

There are unavoidable barriers to establishing segregating populations for subsequent identification of molecular markers in *Musa*. For any reliable genetic study, homozygous parental lines are a must, and such parental lines are practically non-existent in *Musa*. Plus, populations from backcrosses to each parent and an F_2 population would have to be produced and evaluated, and it is practically impossible to do this because of sterilities (both male and female) in the most indicated parental lines for these studies. For example, the PJB diploid is a preferred parental line in these studies because of its resistance to race 4 of Panama disease and to the burrowing nematode. However, PJB is so highly sterile that it cannot be used in cross-pollinations for this purpose.

My suggestion would be that the funds available for "molecular marker studies" could, instead, be put to a very valuable practical use by greatly increasing the numbers of bunches pollinated in breeding for the development of dwarf, black Sigatoka-resistant plantain hybrids. (The FHIA-20 and FHIA-21 plantain hybrids described earlier are tall plants like False Horn, and thus, as is False Horn, susceptible to blowdowns by strong winds. A plantain hybrid with a shorter plant height would significantly reduce these losses caused by winds, which, in turn, would lessen the periodic lengthy interruptions in availability of fruit.)

Conclusions

I know of no more urgent food security problem in the world than that confronting the plantain and cooking banana farmers and consumers in Africa. And, I know of no plant disease that currently adversely affects more people (about 70,000,000 in West and Central Africa and at least 30,000,000 in Latin America) than black Sigatoka on plantains. When black Sigatoka spreads throughout East Africa, as is already happening, the production of the main food (the black Sigatoka-susceptible highland cooking bananas unique to this area of Africa) for 20,000,000 people is projected to be reduced by 50% of that currently being produced. Race 4 of Panama disease is already a serious problem in some countries, and if it arrives to Latin America, it would destroy the export banana. The losses of jobs, foreign exchange, and an important tax base, which would go along with such a destruction of the export banana, would devastate the economies of several countries.

However, there is hope because these needs can be addressed by breeding disease-resistant hybrids. In fact, breeding is the only practical solution, and substantial progress has already been made in this regard (some examples of this progress were pointed out in the above descriptions of the development of FHIA-20, FHIA-21, and FHIA-23).

The authors of PRO*MUSA* are to be commended for bringing the great needs for the development of disease-resistant bananas and plantains to the attention of the CGIAR. In this response, I have attempted to emphasize the advantages of supporting a proven breeding programme to accomplish these objectives. I trust that the arguments and illustrations presented will be useful towards determining the best courses of action in this very important *Musa* improvement project.

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