Evaluating bananas: a global Partnership

Results of IMTP Phase II

Compiled by G. Orjeda

The mission of the **International Network for the Improvement of Banana and Plantain** is to sustainably increase the productivity of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

The Programme has four specific objectives:

- To organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved cultivars and at the conservation and use of *Musa* diversity
- To promote and strengthen collaboration and partnerships in banana-related research activities at the national, regional and global levels
- To strengthen the ability of NARS to conduct research and development activities on bananas and plantains
- To coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

Since May 1994, INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI).

The **International Plant Genetic Resources Institute** (IPGRI) is an autonomous international scientific organization, supported by the Consultative Group on International Agricultural Research (CGIAR). IPGRI's mandate is to advance the conservation and use of plant genetic resources for the benefit of present and future generations. IPGRI's headquarters is based in Rome, Italy, with offices in another 14 countries worldwide. It operates through three programmes: (1) the Plant Genetic Resources Programme, (2) the CGIAR Genetic Resources Support Programme, and (3) the International Network for the Improvement of Banana and Plantain (INIBAP).

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UNDP's mission is to help countries in their efforts to achieve sustainable human development by assisting them to build their capacity to design and carry out development programmes in poverty eradication, employment creation and sustainable livelihoods, the empowerment of women and the protection and regeneration of the environment, giving first priority to poverty eradication.

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IPGRI Headquarters
Via delle Sette Chiese 142
00145 Rome
Italy

INIBAP
Parc Scientifique Agropolis
34397 Montpellier Cedex 5
France

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Special thanks go to Elinor Lipman who undertook the final proofreading of the report and to Florence Malafosse who was responsible for the design and layout.

Foreword

Banana breeding is a slow and difficult task. Apart from the technical difficulties resulting from the almost complete sterility of many of the important varieties, regional and local needs vary considerably. Banana breeding programmes are few in number, and it is therefore a tribute to the hard work and dedication of the breeders involved, that excellent progress has been made in recent years. It is scarcely more than ten years since the first improved varieties were made available for testing by FHIA. Since then, the number of new varieties being produced by breeding programmes has increased exponentially and INIBAP is proud to be able to present herewith the results of the second phase of its multilocation testing programme, IMTP.

INIBAP was able to launch the International *Musa* Testing Programme thanks to funds provided by UNDP. The programme developed from a small programme operating mainly in Latin America in the first phase, to a truly global effort in Phase 2. The evaluation protocols used in IMTP were developed and agreed upon by groups of specialists, thus the programme played an important role in bringing together *Musa* researchers at the global level. Of course the major players in IMTP are the participating National Programmes. In Phase 2, all the costs of the evaluation sites were borne by the hosting institutes and this publication is a result of the hard work and dedication of national scientists.

The second phase of IMTP was coordinated by Dr David Jones until 1995 and since 1996 by Dr Gisella Orjeda. They have been the liaison among participating scientists, breeding programmes and pathologists. This publication provides details of evaluation trials carried out at 16 sites worldwide. With the exception of the sites of Tonga and Nigeria, the statistical analysis of the data presented in this report was carried out by Gisella Orjeda, who also wrote this report. Dr Orjeda also developed a database that includes all the results presented in this publication in a user-friendly manner. The database will be available through Internet shortly.

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IMTP Phase II

Synthesis of final results

The International *Musa* Testing Programme (IMTP) Phase II - Synthesis of final results

Gisella Orjeda[1], Jean Vincent Escalant[1] and Natalie Moore[2]

[1] INIBAP, Parc Scientifique Agropolis II, 34397 Montpellier Cedex 5, France
[2] Queensland Department of Primary Industries, 80 Meiers Road, Indooroopilly, Qld 4068, Australia

Introduction

The International *Musa* Testing Programme (IMTP) was established in 1989 as a cooperative partnership between National Agricultural Research Systems (NARS), INIBAP, breeding programmes and pathologists from six institutes with the support of the United Nations Development Programme (UNDP). The aim was to identify in multilocational trials around the world resistant banana and plantain hybrids which would meet local requirements and with which small-scale farmers could replace existing susceptible cultivars. Another objective of IMTP was to stimulate breeding by providing information to breeding programmes on the pathological response of their improved cultivars under different ecological conditions. As a spill-over effect, IMTP also helped to increase the capacity of national organisations to carry out research on bananas and plantains.

The programme began evaluating germplasm from the *Fundación Hondureña de Investigación Agrícola* (FHIA) breeding programme for resistance to black Sigatoka (*Mycosphaerella fijiensis*). Seven tetraploid hybrids with wide genetic backgrounds were tested along with several reference diploid clones (both wild and edible) that represented the whole range of reaction to black Sigatoka, from highly resistant to highly susceptible. The observation plots consisted of 10 plants per genotype surrounded by a line of Grande Naine or other susceptible cultivar. The whole trial was also surrounded by guard rows of Grande Naine to ensure the presence of the inoculum.

The experiments were established in six countries. Some research partners were provided with training, technical guidelines and funding to carry out the experiments. Four years later a report was published that presented the detailed results of IMTP (Jones and Tézenas du Montcel 1994). The recommendation was made to release three clones for distribution: the clones FHIA-01 and FHIA-02, both dessert banana cultivars with outstanding performance and high resistance to black Sigatoka, and FHIA-03, a cooking banana also with excellent performance and resistance to black Sigatoka. Over the last 10 years these three clones have been distributed to more than 50 countries worldwide.

The success of IMTP phase I encouraged the growth of the programme and INIBAP was requested to develop the initiative further. In 1991, another proposal was submitted to UNDP and approved for a total of three years. The proposal also included support to breeding programmes, virus indexing of the germplasm donated by breeding programmes, support to research on viruses, publication of results, and staff. This time no funds were allocated for the establishment and maintenance of trial sites. However, most NARS decided, given the relevance of IMTP for their programmes, to finance the trials themselves.

For IMTP Phase II, all aspects of the programme were expanded. Instead of evaluating germplasm for resistance to only one pathogen, germplasm was evaluated for resistance to three diseases, black Sigatoka (*M. fijiensis*), yellow Sigatoka (*M. musicola*) and Fusarium wilt (*Fusarium oxysporum* f.sp. *cubense*). Four breeding programmes contributed germplasm (Jones 1994); the material was propagated by the INIBAP Transit Centre (ITC) and delivered as *in vitro* plantlets. The number of sites that asked for testing material increased dramatically from six to 37 (Table 1), despite the fact that the trials were financed at the sites' own expense.

The majority of IMTP Phase II trials were planted during 1996 and 1997. This complete report includes results from the Fusarium (*Foc*) sites in Australia, Brazil, Honduras, Indonesia, Malaysia, the Philippines, South Africa, Spain, Taiwan, and Uganda, as well as from the black Sigatoka (BS) sites in Cameroon, Costa Rica, Honduras, Nigeria[1], the Philippines, Tonga and Uganda and for one yellow Sigatoka (YS) site in Colombia (Figure 1).

Although many sites provided data, a complete analysis was not possible due to missing data following natural catastrophes and incomplete data collection at some sites. These sites included one *Foc* site in Australia, one yellow Sigatoka site in Cameroon, three sites in Cuba (1 BS, 1 YS and 1 *Foc*), five sites in India (two YS and three *Foc*), two *Foc* sites in Indonesia, one *Foc* site in Malaysia, one YS site in St. Lucia and two sites in Thailand (1 *Foc* and 1 YS).

This reports presents both a summary of all compiled data for easy comparison and individual country reports. To obtain further copies of this report please write to the IMTP coordinator at INIBAP.

Procedure used for the analysis of data

For the Sigatoka sites, the experimental design was a randomised complete block design (RCBD) with twelve genotypes, five replicates or blocks and five plants per plot. The experimental unit was the plot of five plants and all the analyses were made with the average of these. For the Fusarium wilt sites the experimental design was a complete randomised design (CRD) with 22 genotypes and 20 plant replicates, the experimental unit was each replicate. In both cases susceptible and resistant reference clones as well as the local cultivar of the area were included as controls.

Research partners were provided with evaluation protocols and at the end of the trials, they provided the raw data to the IMTP coordinator. Raw data from various sites were imported into Minitab v. 12.2 for analyses. The analyses are presented by country. A global summary and discussion are also presented below.

Sigatoka disease sites

Agronomic traits

Description of data

All the country reports present graphics of the averages in the form of boxplots accompanied by tables with the actual mean values and coefficients of variance.

A boxplot consists of a box, whiskers, and outliers (Figure 2). A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits:

Lower Limit: Q1 - 1.5 (Q3 - Q1)

Upper Limit: Q3 + 1.5 (Q3 - Q1)

Outliers are points outside of the lower and upper limits and are plotted with asterisks (*).

[1] As the experimental design was completely different from the rest of IMTP sites the results obtained in Nigeria could not be included in the global summary but they are included in the country reports section.

Figure 1: IMTP locations

In the global summary we present a table with the average of each genotype for number of days to harvest, bunch weight, number of hands and average fruit weight for all the sites (Table 2). We also present one main effects dual graphic illustrating the average bunch of the improved cultivars in each site as a general measure of the quality of the site and the average bunch weight of the improved cultivars and some landraces across sites (Figure 4).

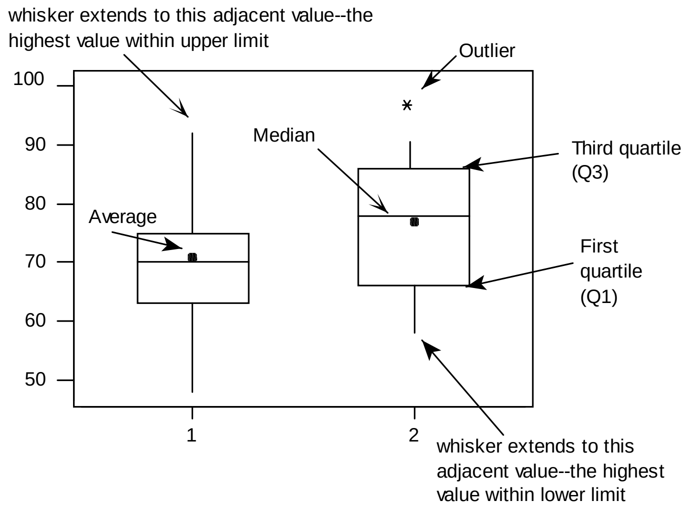


Figure 2: Example of boxplots and explanation of symbols

Analysis of variance and comparisons of means

For the agronomic traits data in each country, a two-way analysis of variance was used with blocks and genotypes as sources of variation. Following the analysis of variance, the means of each genotype were compared with the local cultivar mean using Dunnett's procedure. A one-side comparison was used (Figure 3a). This multiple comparison of means was useful to determine, for example, better yielders or taller clones than the local cultivar ($p<0.05$).

Stability of cultivars

Stability was analysed globally. Linear regressions of the environmental index on the varietal averages of various important traits were performed. The environmental index of each site was used as the independent variable and the varietal average was used as the dependent variable.

The environmental index is a variable that measures the difference between the average of a given environment with respect to the global average for a given trait. It is obtained by simply subtracting the site average for a given trait from the average for the same trait considering all sites. For example for bunch weight, a positive value of the environmental index indicates a better than average performance of a site while a negative value indicates the opposite.

The regression equation of the environmental index on cultivars is a good method to estimate the response of a cultivar to a unit of improvement of the environment. A slope (β) of one is characteristic of stable cultivars because it indicates that the cultivar changes its average response in the same measure as the general performance of the site. A slope higher than one indicates a positive response where the genotype improves at a higher rate than the environment average. It means that the cultivar responds better than expected under a positive environment. On the other hand, the interpretation of the slope (β) for disease

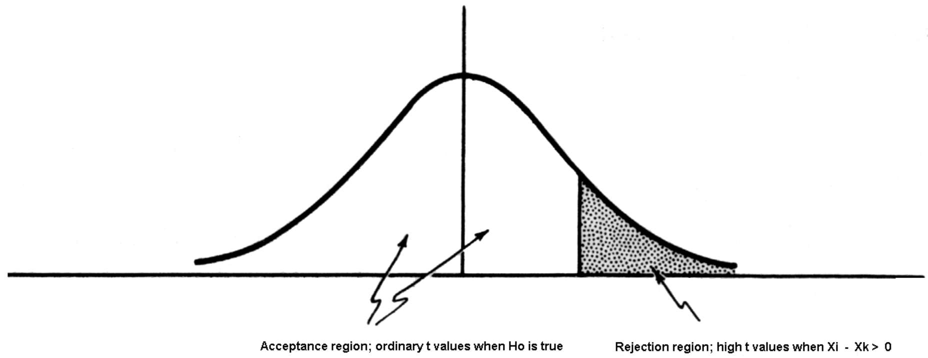
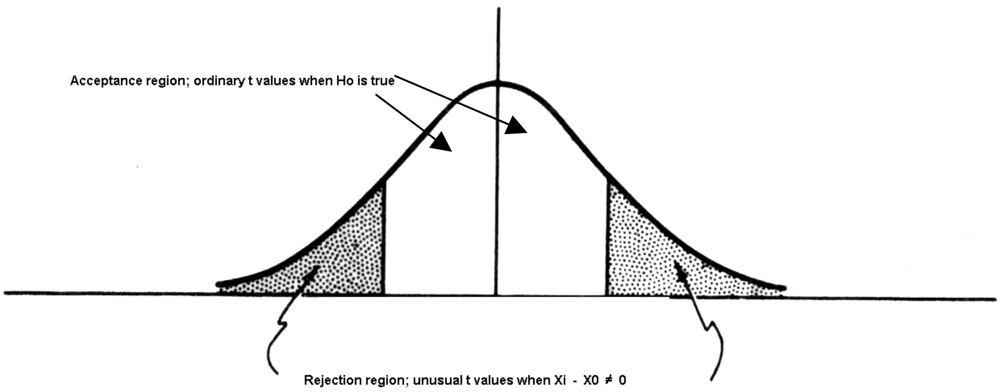


Figure 3a: One-sided Dunnett test used for comparisons of means of agronomic traits

Ho : $8_i \leq 8_k$ where: i = treatment genotypes
Ha : $8_i > 8_k$ k = control



Ho : $8_i = 8_k$ where: i = treatment genotypes
Ha : $8_i \neq 8_k$ k = control

Figure 3b: Two-sided Dunnett test used for comparisons of means of disease traits

resistance is quite different as the desired situation is that the average response of the cultivar changes to a lesser degree than the general infection score of the site. A slope (β) lower than one indicates a positive homeostatic response where the genotype shows lower infection scores than the site average. It means that the cultivar keeps is resistance / tolerance under higher pathogen pressure. Table 3 presents the regression and correlation coefficients as well as the probability (p) to test whether the null hypothesis of the regression coefficient β is equal to zero. A selection of some interesting regressions are plotted in Figure 5a-d. In general terms, only improved cultivars and significant regressions were chosen to allow for readability of the graphics.

Infection Index (II), Disease Development Time (DDT) and Youngest Leaf Spotted (YLS)

Description of data

The infection index is a number that expresses the amount of leaf area affected by the Sigatoka pathogen and is calculated using Gauhl's modification of Stover's Sigatoka severity scoring system and the following formula:

$$\text{Infection index} = \frac{\sum nb}{(N-1)T} \times 100$$

Where:

n= number of leaves with same disease grade

b= grade

N= number of grades used in the scale (7*)

T= total number of leaves scored

The calculation of the infection index uses 7 disease grades (Jones 1994).

The infection index was recorded at three stages during the plant cycle, at six months after planting, at bunch emergence and at harvest. Data was described in a similar way as the agronomic data (see above). In each country report a graphic illustrating the progression of the infection index during the plant cycle is presented to compare all genotypes at each location. Also in the country reports, tables with the average and coefficient of variation of the disease development time (DDT) and youngest leaf spotted (YLS) are presented. In the global summary we present a table with the average and coefficient of variation of the infection indices at the three evaluation times (Table 4), and the DDT and the YLS per genotype and country (Table 5). As was the case for bunch weight, a main effects dual graphic is also presented for the average infection indices at bunch emergence per country and per genotype. In this case the graphics serve to visualise the relative pathogen pressure on each site and the average response of the treatment genotypes across sites (Figure 6).

Analysis of variance and comparisons of means

For each country, an analysis of variance of the infection index was carried out for each evaluation time. Then, all treatment means were compared, first to the susceptible reference mean and then to the resistant reference mean. Two consecutive two-sided Dunnett tests were used with the aim of detecting firstly those genotypes that presented a more, an equally or a less susceptible phenotype than the susceptible control and secondly, genotypes that were more, equally or less resistant than the resistant control (Figure 3b).

Stability of the cultivars

The same procedure as with the agronomic traits was used for the infection index at bunch emergence, for the DDT and for the YLS. An environmental index was obtained for each variable per site and linear regressions of these on the cultivar averages were performed (Figure 7a-c). The regression and correlation coefficients for these traits are presented in Table 6.

Reference clones used for the analyses

Calcutta 4 was planted in all trials as the highly resistant clone. However it was not used for the comparisons of means in all countries. Calcutta 4 is a clone with a hypersensitive response, therefore its infection index should be always zero.

Pisang Lilin, another resistant landrace, was also planted in all trials as the highly resistant reference clone. Unfortunately due to problems with tissue culture, very weak dwarf somaclonal variant plants of this accession were used at all locations. These plants could not, therefore, be used as a reference clone as intended.

Pisang Ceylan, a landrace that has been selected to be the partial resistant reference for the next round of IMTP, was also planted in all trials of IMTP Phase II. This clone was, in the absence of other suitable resistant clones, used as a resistant control for the Dunnett multiple comparisons of means in some countries.

Pisang Berlin was used as the susceptible reference clone. In one or two trials where this clone was not planted, the analysis was done using Niyarma Yik, the highly susceptible reference clone.

Fusarium wilt sites

Agronomic traits

Description of the data

Data were treated similarly as in the Sigatoka trial sites. Each country report presents tables with averages and boxplots graphics for all traits evaluated. In the global summary, as was also the case with the Sigatoka sites, a table is given with the average of each genotype for bunch weight, number of days to harvest, number of hands and average weight of fruits for all the sites (Table 7). This report also presents one main effects dual graphic illustrating the average bunch of the improved cultivars and some landraces in each site as a general measure of the quality of the site to grow the improved genotypes, and the average bunch weight of each improved cultivar across sites (Figure 8).

Analysis of variance and comparisons of means

For the agronomic traits a one-way analysis of variance was used with genotypes as the source of variance. Following the analyses of variance for each country, the means of each genotype were compared with that of the local cultivar. A one-side Dunnett comparison of means with a control was used in the same way as in the Sigatoka analyses (see above for explanation).

Stability of cultivars

A regression of the four main agronomic traits on the environmental index was performed (see Sigatoka sites above for description of method). The regression and correlation coefficients are presented in Table 8, and some interesting regression lines are presented in Figure 9a-d.

Internal symptoms

The internal symptoms score was also analysed using a one-way ANOVA. The one-side Dunnett test was performed using the Fusarium susceptible reference clone specified by the protocol. A different reference clone was used depending on the Fusarium race present at the site. For each country a table of the internal symptoms with the average, minimum and maximum values as well as number of plants evaluated is presented. In the summary section we present a compilation of all these data in a single table (Table 9). We also present in this summary two dual graphics (one per *Foc* race) showing the averages and standard deviations of the internal symptom scores averaged per site and per genotype across sites (Figures 10 and 11).

External symptoms

The Fusarium evaluation protocol also specified scoring seven external symptoms once a month, beginning three months after planting, with the aim of visualizing whether there was a clear evolution of the symptoms. Each country report therefore presents a graphic of the evolution of each external symptom per genotype throughout the experiment.

Diversity of Foc *across IMTP trial sites*

Samples of dried discoloured vascular tissue from the pseudostems of infected plants were prepared by staff at each site and sent to the Plant Pathology Unit, DPI, Indooroopilly, Queensland, Australia for analysis. *Foc* was isolated from affected tissue and monoconidial cultures prepared for each isolate. To characterise isolates of *Foc*, vegetative compatibility groups (VCG) analysis and volatile production were carried out at the DPI laboratories and DNA fingerprinting using the DNA. Amplification Fingerprint (DAF) analysis was conducted by Dr Suzy Bentley at the CRC for Tropical Plant Pathology laboratories. The results of the analyses are presented in Table 10. These techniques are briefly described below.

Vegetative compatibility group (VCG)

Vegetative compatibility characterises groups of isolates based on the genetic relationships within the fungal populations rather than host-pathogen interaction. This technique differentiates isolates that have identical alleles at each of the loci that govern heterokaryon formation and thus vegetative compatibility. These loci are referred to as vegetative incompatibility (*vic*) or heterokaryon (*het*) loci. On the basis of heterokaryon formation, isolates of *Foc* can be divided into genetically distinct groups known as vegetative compatibility groups (VCGs) (Correll *et al.* 1987). The technique developed by Puhalla (1985), is based on the generation of nitrogen non-utilising (*nit*) mutants, and enables heterokaryon formation to be scored macroscopically, making VCG analysis amenable to population studies.

Volatile production

Brandes (1919) found that isolates of *Foc* grown on steamed rice either produced or did not produce a characteristic volatile odour. Stover (1962) also used volatile compounds to differentiate strains of this pathogen. Stover assigned isolates to either the 'odoratum' or 'inodoratum' group, based on the presence or absence of volatile substances. This technique has been used to characterise Australian and Asian isolates of *Foc* (Moore *et al.* 1991, Pegg *et al.* 1993, 1996). These studies indicated that the production of volatile compounds on rice medium could be used to differentiate between strains of *Foc*. There was absolute correlation between the production of volatile substances and VCG. Volatile analysis is a simple and inexpensive method of characterizing isolates of *Foc* based on the biochemistry of cultures *in vivo*.

DNA fingerprinting

Arbitrary Primer Technology (APT) methods such as Random Amplified Polymorphic DNAs (RAPDs) and DNA Amplification Fingerprinting (DAF) are popular techniques for generating DNA markers for genetic mapping, molecular taxonomy and molecular diagnostics. These techniques generate genome-specific DNA banding patterns in a polymerase chain reaction (PCR)-based DNA amplification reaction directed by a single oligonucleotide primer of arbitrary sequence. APT methods are useful for quickly and conveniently estimating genetic variation. Using these methods, it is possible to generate a genomic ‘fingerprint’ that can be used to assess genetic variation both within and between populations of organisms (e.g. VCGs). The DAF technique has been used to assess the genetic variation among isolates within VCGs and between different VCGs of *Fusarium oxysporum* f.sp. *cubense* worldwide (Bentley *et al*. 1998). Isolates within each VCG of *Foc* generally produce an identical DNA fingerprint pattern and are closely related, regardless of geographic origin or host source.

Results

Sigatoka *disease trials*

General considerations

In the overview of IMTP Phase II presented in INFO*MUSA* (Orjeda et *al*. 1999), only the results obtained in Costa Rica, Cameroon and Tonga were presented as representative examples for Latin America, Africa and Asia/Pacific respectively. The results of other locations appeared to be very affected by “El Niño” or other particular problems, which decreased yields and masked the real effects of the disease (see country reports), and were not considered for the discussion and classification of hybrids. In this global summary however, all participating locations are considered and results obtained in Costa Rica (plant crop), Cameroon and Tonga will be mentioned as comparative references.

The agronomic performance of the four hybrids that were tested varied greatly depending on the location. Figure 4 provides an overview of the main effects of the genotype and site on the average bunch weight considering only the improved hybrids, Yangambi Km 5 and the local cultivar. The most favourable location for yield was on average Costa Rica (ratoon crop). Second best yields were obtained in Cameroon (ratoon crop). Tonga, Costa Rica (plant crop) and Honduras had average yields and Uganda and Philippines had lower than average yields. It is to be noted that the infection index was inversely correlated with the production traits such as bunch weight, number of hands, number of fruits, average weight of fruits (p <0.01 for all, Table 11).

The disease development time (DDT) is a very reliable parameter for evaluating resistance levels when accurately recorded. During this IMTP phase, Calcutta 4 and Yangambi Km 5 were reported to present the development of the disease (Table 5). Moreover, normally the DDT should be negatively correlated with production parameters. However correlation data of several locations showed that this was not always the case, suggesting that there might be difficulties in interpreting the leaf symptoms in certain situations (Table 11). For example, when disease pressure is high, numerous lesions of stage 1 can occur simultaneously and can coalesce, closely resembling a necrotic lesion of stage 6. In contrast, the youngest leaf spotted (YLS) and the infection index (II) appear to be less difficult for the evaluators to qualify. Moreover, the YLS and the II are highly correlated with the DDT, $R^2 = 0.848$, $p<0.01$ and $R^2 = -0.952$, $p<0.01$ respectively. Therefore, these two variables can be considered very reliable parameters for evaluating resistance levels. Since they are easier and faster to record and highly correlated to DDT they are more appropriate tools for the classification of new hybrids than DDT and will be used in this report.

The only institute that finished a yellow Sigatoka trial was CORPOICA in Colombia; please see the country analysis for results.

Agronomic performance and response to disease

Improved cultivars

Hybrids from FHIA gave very good yields (Table 2). Bunches of FHIA-23 and SH 3436-9 (somaclonal variant of FHIA hybrid SH 3436 obtained by INIVIT) weighed on average 31 kg and 24.2 kg respectively across sites with a maximum bunch weight average of 39.3 kg for FHIA-23 in Cameroon and a maximum bunch weight average of 28.8 kg for SH 3436-9 in Tonga. The yields of the EMBRAPA hybrids were lower, with average bunch weights of 10.6 and 9.9 kg across sites for PV 03.44 and PA 03.22 respectively (Figure 4).

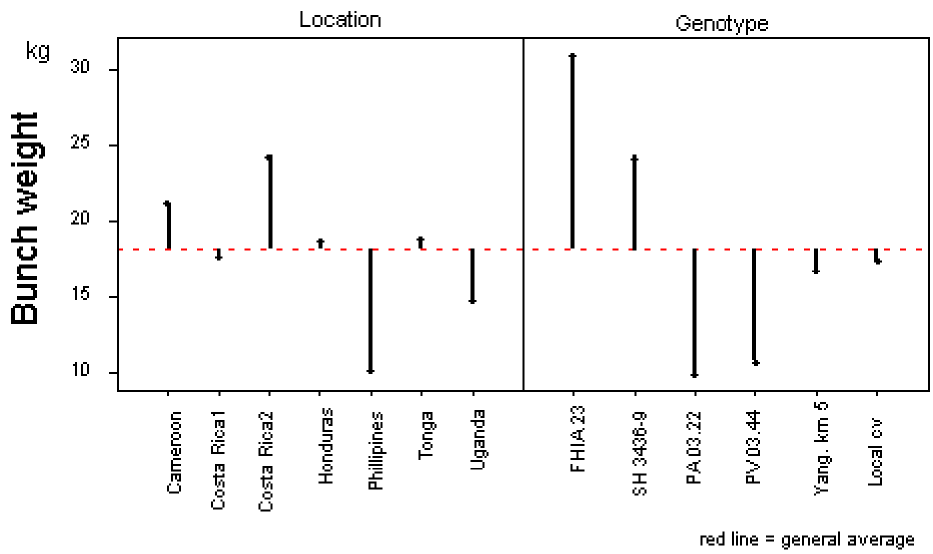


Figure 4: Main effects plot - Data means for bunch weight. Black Sigatoka sites

Although the local cultivars differ between countries, it is interesting to note that their average across sites is 17.7 kg, with a maximum average of 22.7 kg (Williams) in Tonga and a minimum average of 10.5 kg (Lakatan) in the Philippines. These averages reinforce the good performance of the FHIA hybrids (Figure 4 and Table 2). A Dunnet comparison of means using data from all locations was carried out (analysis not shown). FHIA-23 had a longer cycle compared to local references (p<0.01), with an average of 474.9 days; SH 3436-9 (423.7 days) had an average cycle no different from that of the local cultivars (p=0.1421). Despite the longer cycle of FHIA-23, its productivity (production/year) remained the highest and was significantly superior to that of the local cultivars (p<0.01). Similarly the productivity of SH 3436-9 was significantly superior to that of the local cultivars (p<0.05).

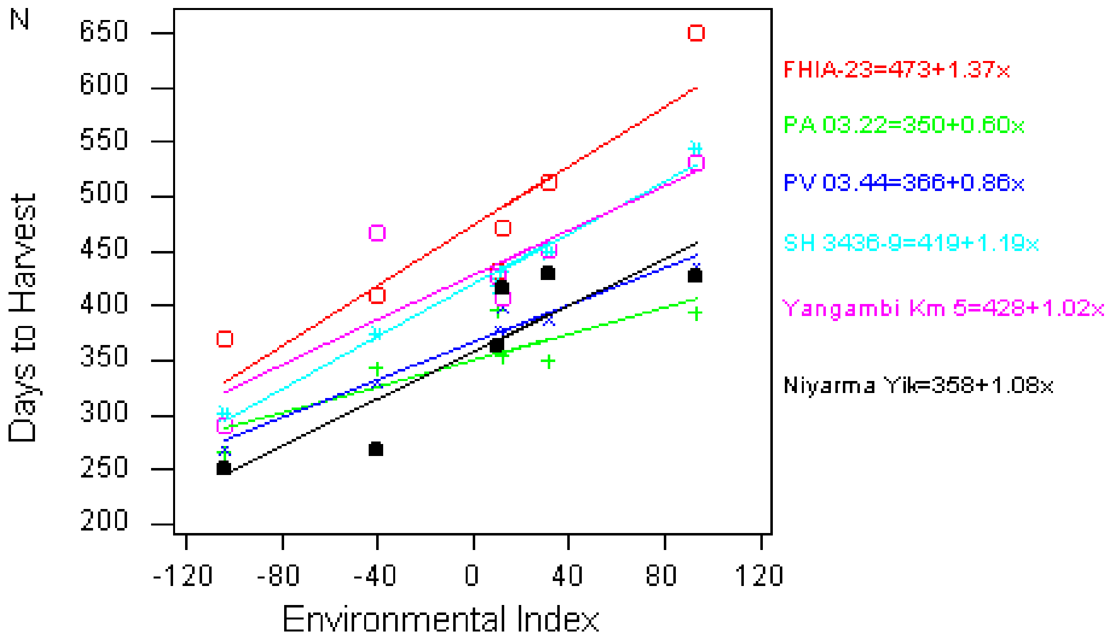


Figure 5a: Regression days to harvest - environmental index. Sigatoka trials

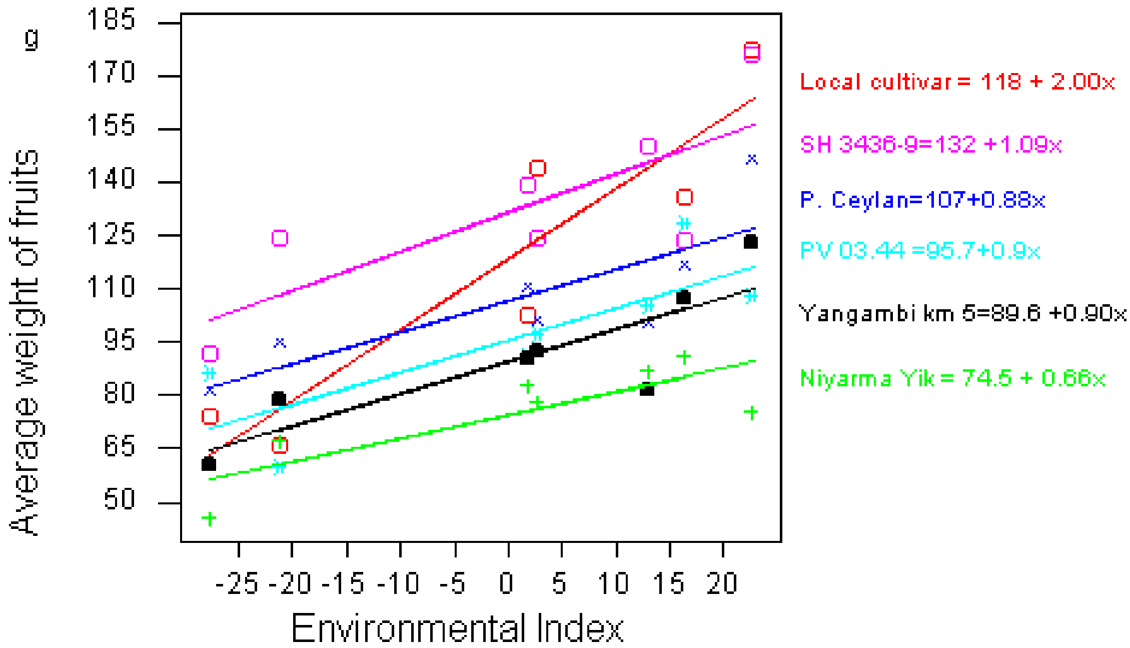


Figure 5b : Regression bunch weight - environmental index. Sigatoka trials

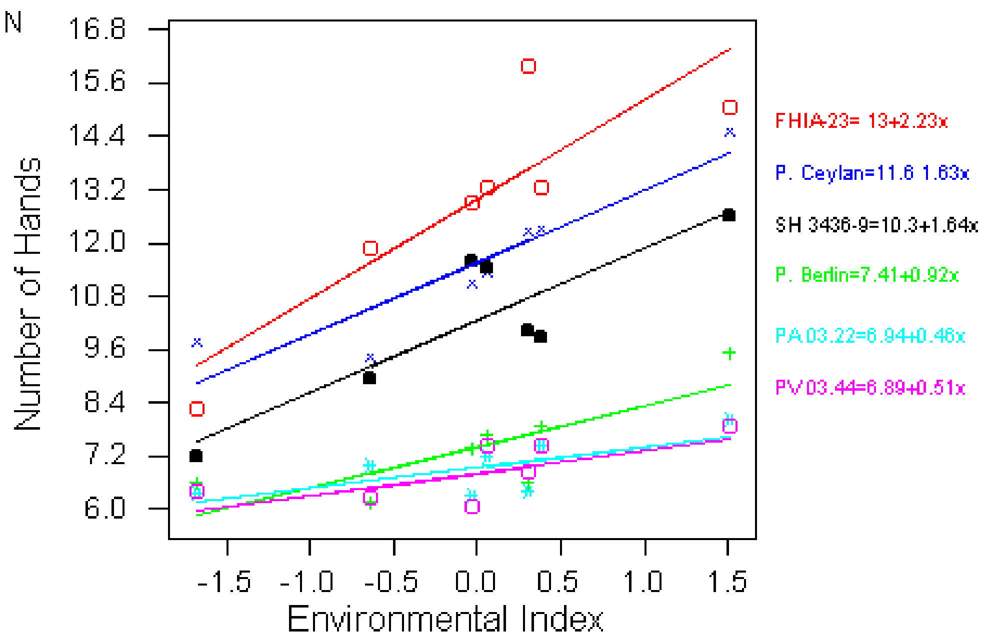


Figure 5c: Regression number of hands - environmental index. Sigatoka trials

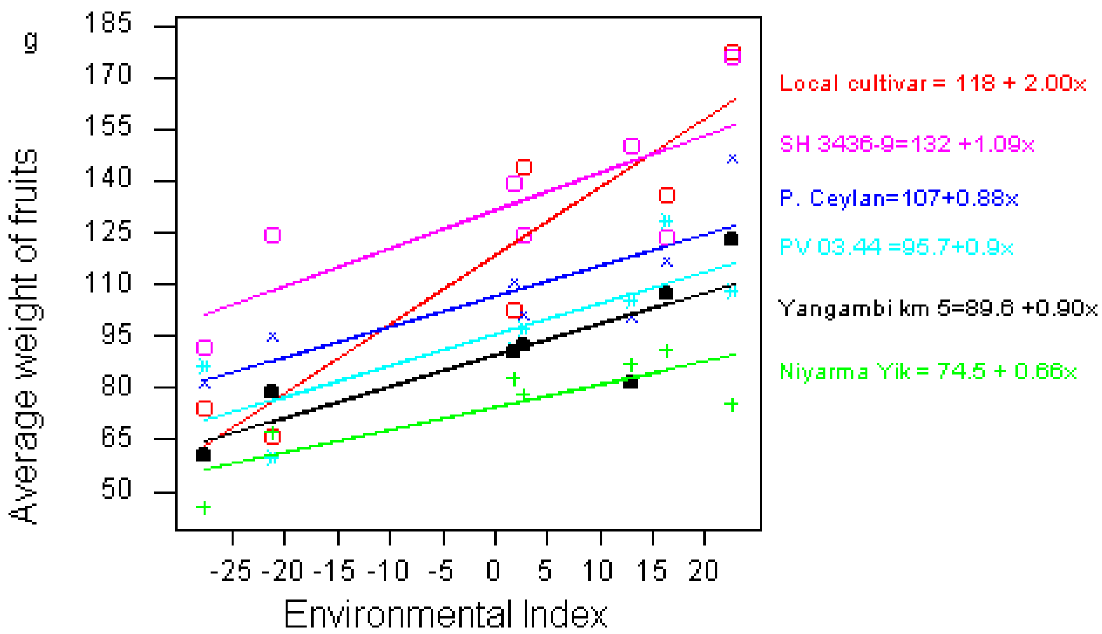


Figure 5d: Regression average weight of fingers - environmental index. Sigatoka trials

When considering all locations, FHIA-23 and SH 3436-9 had average infection indices at bunch emergence of 17.6 and 21.9 (Table 4). These values were not statistically different (p=1 and p=0.6264 respectively) from that obtained by the resistant reference, Pisang Ceylan (18.7) across sites. These II values combined with their bunch weights allow us to conclude that FHIA-23 and SH 3436-9 are tolerant to black Sigatoka disease. This conclusion is consistent with their YLS score (Table 5), which was not statistically different from that of Pisang Ceylan either (p=0.8166 and p=0.1157 respectively). Hybrids from EMBRAPA, Brazil (PV 03.44 and PA 03.22) had average II higher than or no different to those of Pisang Berlin and the local cultivars in most locations (See Dunnett's analysis in country reports).

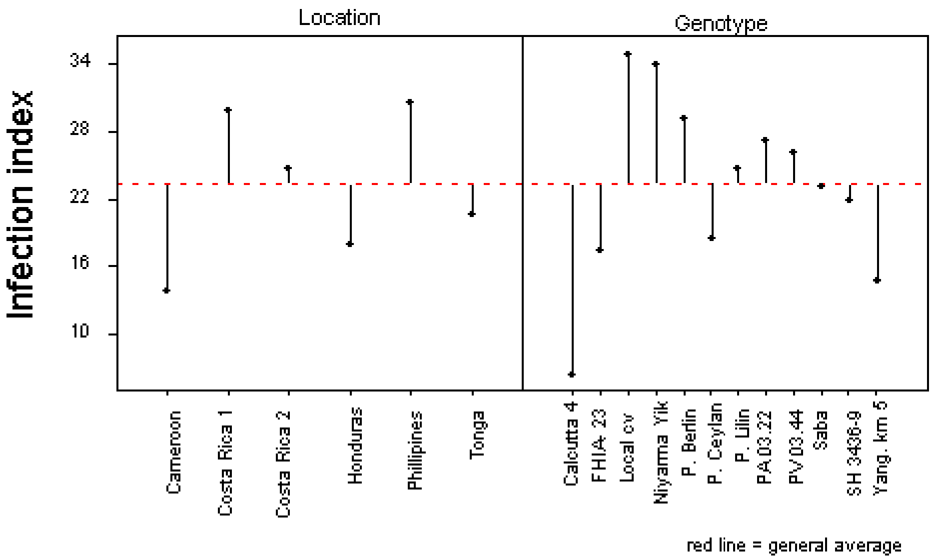


Figure 6: Main effects of site and genotype for the infection index at bunch emergence

Landraces

It is to be noted that during this phase of IMTP II the highly resistant clones Calcutta 4 and Yangambi Km 5 presented necrotic lesions of stage 6 in most locations, except in Cameroon, a result not expected for these clones (Table 4 and 5). This is the first report of *M. fijiensis* breaking the resistance of these two clones. This result indicates that further studies are required to determine if more aggressive strains of *M. fijiensis* are present, or indeed if a new pathogen species is involved in these cases.

Saba had an average infection index across sites. Pisang Lilin, normally a resistant reference, also showed an average response. Since the plants of this clone were somaclonal variants this result should not be considered as the normal response of the clone. Pisang Berlin and Niyarma Yik were, as expected, the most susceptible landraces (Figure 6) only surpassed in average by the local cultivars. See country reports for local cultivar names.

Stability of clones

The improved cultivars, FHIA-23 and SH 3436-9 were very stable for bunch weight with a β value higher than one. They had the same slope, β =1.77 with p<0.05 and p<0.01 respectively. This was the steepest positive slope of all clones, meaning that they produce bunches bigger than expected when the environment improves in one unit (Figure 5a-d). Clone PA 03.22 did not have significant stability (β=0.736, p=0.056) and PV 03.44 had a β=0.369, p<0.05. This means that their bunch weights are not consistent with the inputs of the environment. The same was true in the case of clone PA 03.22 for its stability on the number of hands β =0.46, p=0.082 and for the average weight of fruits β =0.76, p=0.106. For PV 03.44 the stability for the number of hands was non significant with β=0.51, p=0.067, but the average weight of fruits had a β=0.90, p=0.03 (see Table 3 for all clones).

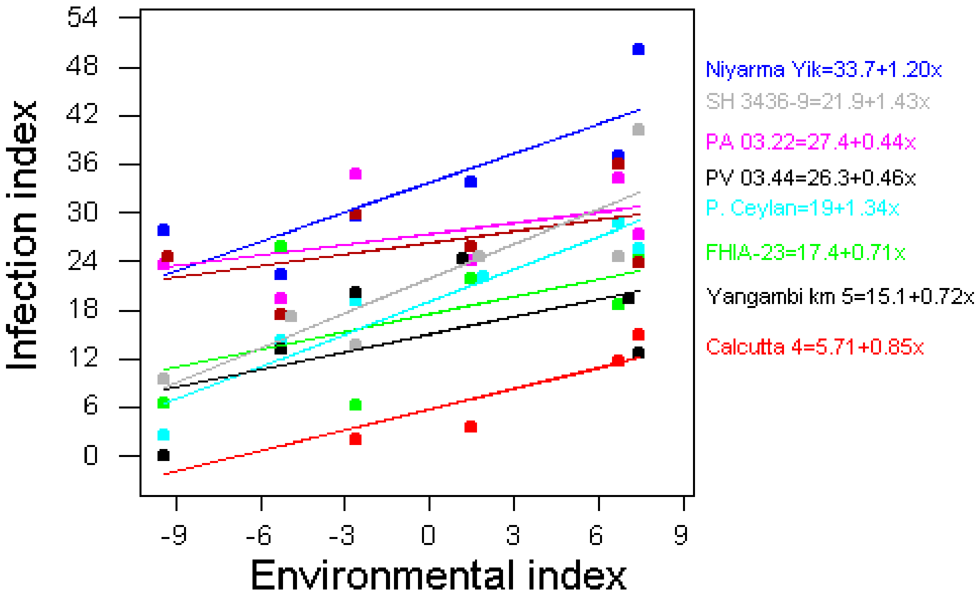


Figure 7a: Regression infection index - environmental index at bunch emergence

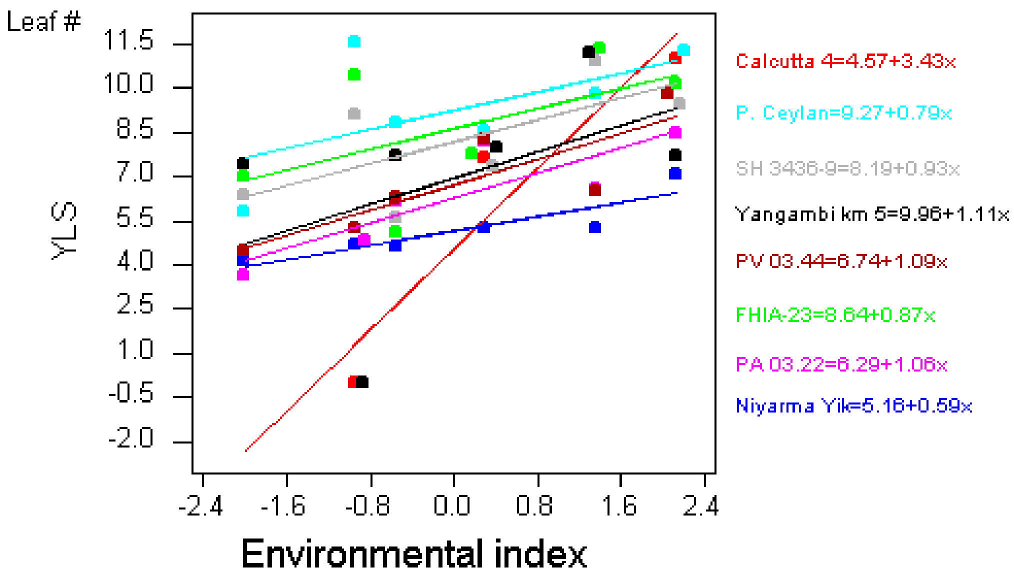


Figure 7b: Regression YLS - environmental index

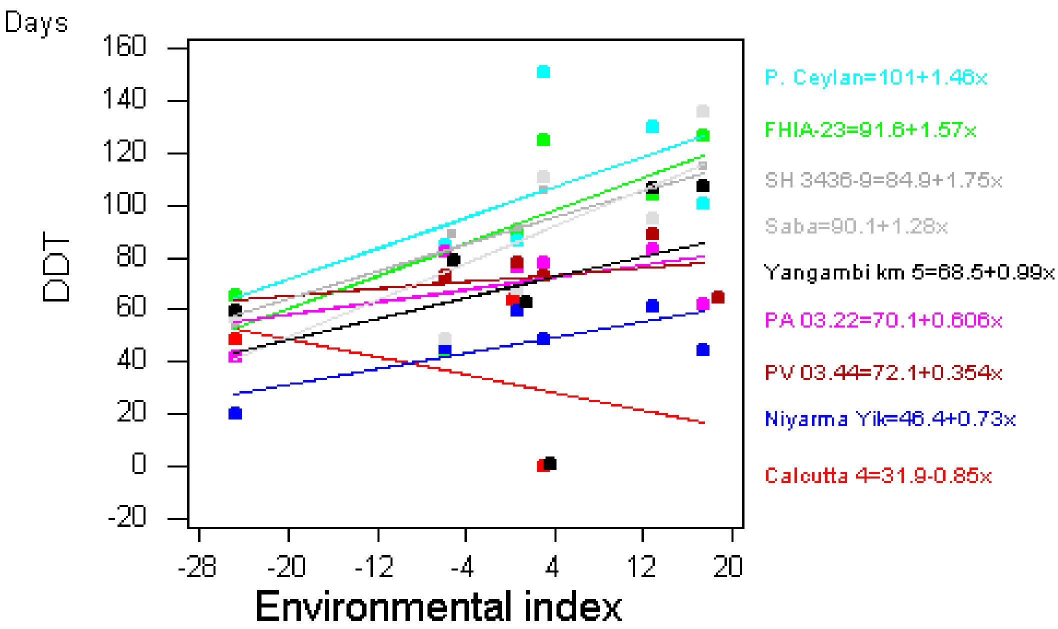


Figure 7c: Regression DDT - environmental index

Fusarium wilt trials

General considerations

Yields were highly variable and depended on the site as was expected. Since many factors, including management, latitude, temperature, pathogen pressure amongst others influence the agronomic performance, it is not possible to make too many generalizations from the results. A correlation analysis between the various agroclimatic factors listed in Table 1 and the environmental index was performed but the correlation coefficients were non significant.

Figure 8 provides an overview of the main effects of genotype and site on the average bunch weight considering only the improved and local cultivars, Yangambi Km 5 and Gros Michel. The most favourable site for yield was Taiwan, where management skills are highly developed. Second best yields were obtained from the Uganda site. It should be noted that this site was in a farmer’s field, indicating the level of care the farmer devotes to get good production.

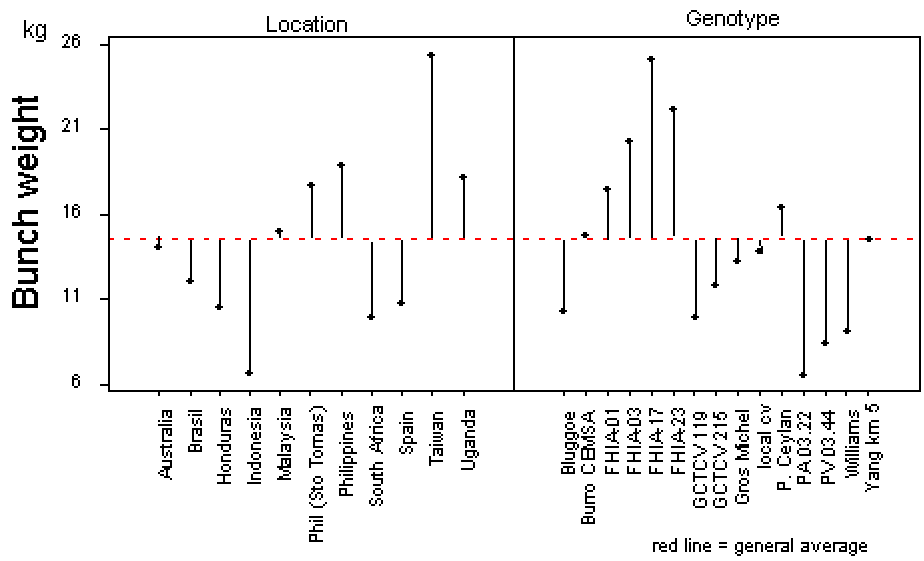


Figure 8: Means for bunch weight. *Foc* sites - Improved cultivars

Internal discolouration of the rhizome was rated from 1 to 6 where 1 indicated no discolouration; 2, isolated points of discolouration; 3, discolouration up to 1/3 of vascular tissue; 4, discolouration between 1/3 and 2/3 of vascular tissue; 5, discolouration of more than 2/3 of the tissue and 6 indicated total discolouration.

Breeding programmes have used the internal discolouration of the rhizome to estimate the resistance of the genotype to *Foc*. Furthermore, this value combined with the agronomic performance is a measure of the tolerance of the accession. However, in the case of IMTP Phase II it has been quite difficult to make an overall estimation of the resistance or tolerance of the plant genotype to *Foc* due to large differences in ratings across sites. It is believed that the differences were due to a subjective element of visual interpretation and not only to the differences in pathogen pressure. The internal symptom average for each site can be considered a general measure of the pathogen pressure confounded with the effect of visual interpretation (Figures 10 and 11). This is particularly true for discolouration averages across sites infested with *Foc* race 1 as there were only three sites infested with this race in the whole IMTP trial and one of them (Bago Oshiro in the Philippines) had exceptionally high averages (Figure 10).

The overall averages mentioned below should therefore be considered with caution. For comparisons with the reference clone, and resistance or tolerance ratings it is preferable to use the average scores of each genotype within site (Table 9).

Agronomic performance and response to disease

Improved cultivars

Sites infested with *Foc* race 1

Foc race 1 was present in Brazil, Honduras and The Philippines (Bago Oshiro). The VCGs are listed in Table 10. The average score considering all genotypes across sites infested with *Foc* race 1 was 2.4 (Table 9, Figure 10). The susceptible reference clone Gros Michel had an average score of 3.2 across sites. The improved genotype with the lowest discolouration score across sites was GCTCV 119, a Giant Cavendish (AAA) tissue culture variant developed by the Taiwan Banana Research Institute (TBRI). This clone had an overall score of 1.3, which reflects its resistance to *Foc* race 1.

The genotype with the second lowest discolouration score was FHIA-23, an AAAA hybrid between Gros Michel Highgate x SH 3362. This hybrid had an average discolouration score of 2.1 on sites infested with *Foc* race 1. Although this score was below the overall average and it was the lowest for *Foc* race 1 of all FHIA hybrids, it already indicates infection in the corm. Given its excellent yield (Figure 8), this hybrid can be classified as very tolerant. It remains to be tested in the following generations to verify tolerance stability.

FHIA-01, an AAAB tetraploid hybrid obtained from crossing Prata anã x (Prata anã x SH 3142) showed an average score of 2.2. Although the scores of FHIA-01 already indicate more than isolated points of discolouration in the vascular tissue, they are still lower than the general average score. Despite its yield being the lowest of the FHIA hybrids, FHIA-01 showed the lowest variance across sites amongst the FHIA hybrids. These results suggest that FHIA-01 is tolerant to *Foc* race 1. This hybrid performs well under a variety of environments and responds positively to good management conditions.

PV 03.44, a Pome-type (AAAB) tetraploid hybrid was developed by EMBRAPA/ CNPMF from a cross between Pacovan and Calcutta 4. It had an average score of 2.3 on sites infested with race 1, which was just under the general average for these sites. However its yield was usually low with a general average of 8.4 kg and a maximum average of 11.3 kg in South Africa.

GCTCV 215 is also a tissue culture variant obtained from Giant Cavendish (AAA) by TBRI. It had an average score of 2.5 for race 1 sites, higher than that of GCTCV 119 and slightly higher than the overall average. However it is to be noted that this average is substantially influenced by the exceptional high scores (5.6) recorded in one site in the Philippines (Bago Oshiro). On the other two sites infested with race 1, this genotype had an average score of one (no discolouration). Since this genotype was always considered to be resistant to race 1 these contradictory results deserve re-evaluation.

FHIA-17, an AAAA hybrid obtained by crossing Gros Michel Highgate x SH 3362, had discolouration scores which were above average. Its average score was 2.5 across sites. However as in the case of GCTCV 119 it is to be noted that this average is substantially influenced by the exceptionally high scores (5.6) recorded in one site in the Philippines (Bago Oshiro). On the other two sites infested with race 1, this genotype had an average score of one (no discolouration) which is to be expected for Cavendish clones. FHIA-17 was the best-yielding genotype of all across sites. It had an average weight of 25.2 kg. FHIA has reported this genotype to be resistant to Fusarium wilt race 1. These findings indicate contradictory results among sites that merit further investigation.

FHIA-03, a tetraploid AABB hybrid, had an average vascular discolouration score of 3.08 across sites with *Foc* race 1, the highest score of all the improved genotypes and very similar to that of Gros Michel, the susceptible reference. This score is above the total average score when all the participating genotypes are considered and it certainly indicates susceptibility. Despite its high discolouration score, this hybrid had very good yield with an average of 20.4 kg across sites and maximum average of 29.8 kg. It seems that this genotype shows tolerance in the plant crop cycle. It would be interesting to verify if this tolerance is maintained in further generations.

Sites infested with *Foc* race 4

Foc race 4 was present in Australia, Indonesia, the Philippines (Sto. Tomas), South Africa, Spain and Taiwan. The respective VCGs are listed in Table 10. Williams, the susceptible reference for sites infested with race 4, was a dwarf somaclonal variant that could not be used for comparisons. The average overall discolouration score for the race 4 sites was 2.4 considering all genotypes. GCTCV 119 had an average score of 1.3 across sites infested with race 4 . As in sites infested with race 1, it was also the lowest discolouration score of all the improved cultivars across trial sites. However, there are indications that this genotype can be quite susceptible to *Foc* race 4, although no infection had been recorded for this genotype in the Indonesian site, samples of this genotype sent previously to QDPI confirmed infection. Its average yield was on the lower side with a 10 kg bunch. This genotype was very variable with good average yields of between 15 kg and 22 kg under some conditions and very low (3 kg) in others. It is believed that management practices have a strong influence on the agronomic performance of this genotype.

GCTCV 215 had an average score of 1.7 if data from Indonesia, where only one plant was evaluated, are not considered. This average was the second lowest of all improved genotypes. This somaclonal variant had an average yield of 11.9 kg across sites. However this average increases to 12.7 kg if the data from Indonesia are not taken into consideration. Since this genotype was always considered to be resistant to race 1 and susceptible to race 4 these contradictory results deserve re-evaluation.

FHIA-01 showed an average discolouration of 2.04 across sites infested with *Foc* race 4. This score was similar to the average score of the susceptible clone Williams (2.05). However Williams plants were dwarf somaclonal variants and therefore their score is not reliable. FHIA-01 had an average bunch weight across sites of 17.6 kg and a maximum average of 24 kg with optimum management conditions. Given the good performance of FHIA-01 across sites, this genotype can be classified as tolerant to both races 1 and 4 of Fusarium wilt.

PV 03.44 had a score of 2.1. This score was below the overall average and lower than that of the susceptible references. However its yield was usually low with a general average of 8.4 kg and a maximum average of 11.3 kg in South Africa.

PA 03.22 also had a low score in sites infested with race 4, its score was 2.3. Similarly to PV 03.44, this score was also below the general average across sites and lower than that of the susceptible references. However its yield was also usually very low with an overall average of 6.4 kg and a maximum average of 11.6 kg in South Africa.

FHIA-17 had an average score of 2.5 across sites, as was the same for *Foc* race 1 and race 4 sites. This score is above the overall average and in Taiwan it had a score of 4.3. However, FHIA-17 was the best-yielding genotype of all in these trials. It had an average weight of 25.2 kg across sites and maximum yields of 43.8 kg in Taiwan. Our results indicate that it is very tolerant to race 4 during the plant crop. It remains to be tested to see whether following generations retain this level of tolerance.

FHIA-03 had an average score of 3.09 which means that it had around one third of the vascular tissue showing discolouration on both types of sites. These scores are above the total average score when all the participating genotypes are considered and they certainly indicate susceptibility. Moreover in some sites FHIA-03 had very high discolouration scores (4.3 to 5.7) as in the Canary Islands and Australia. Despite its high discolouration scores, surviving plants of this hybrid gave some very good yields with an average of 20.4 kg across sites and maximum average of 29.8 kg. The only exception to the high yield was in the Canary Islands. In this particular case the data were collected from only two plants.

FHIA-23 had an average score of 3.1, well above the general average indicating susceptibility. Moreover in Australia and the Canary Islands it had an average above 4, which indicates high susceptibility to subtropical race 4. Despite its high discolouration scores, this hybrid was the second best-yielding of all FHIA hybrids with an average bunch weight of 22.3 kg and a maximum average yield of 46.8 kg in Taiwan.

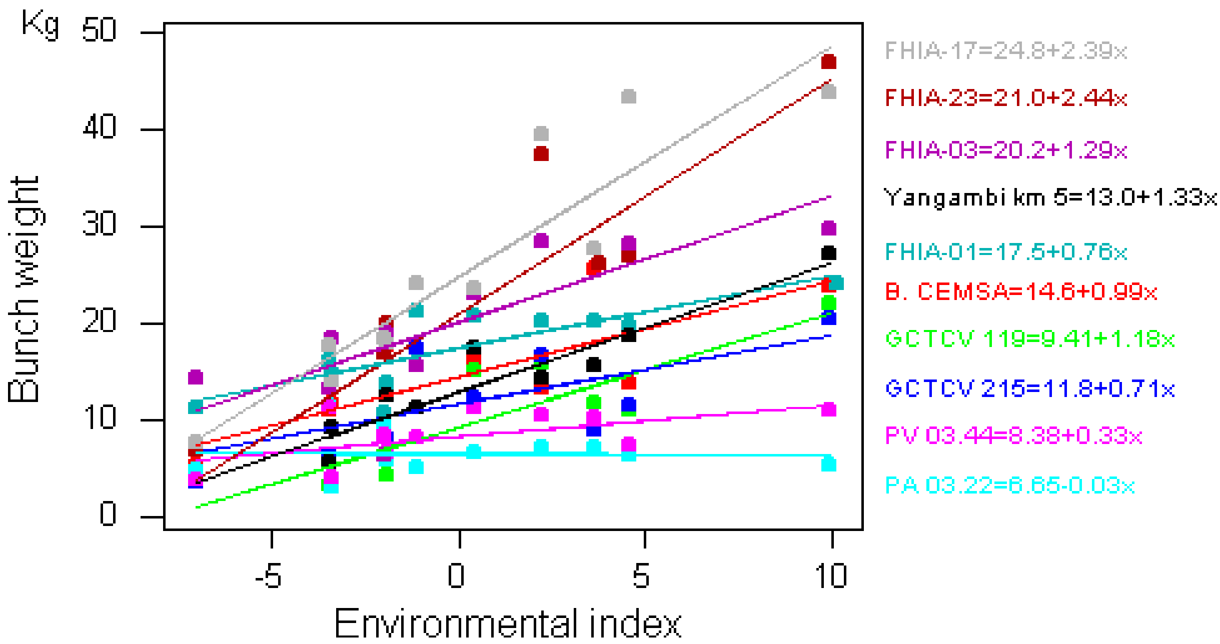


Figure 9a: Regression bunch weight - environmental index. Fusarium trials

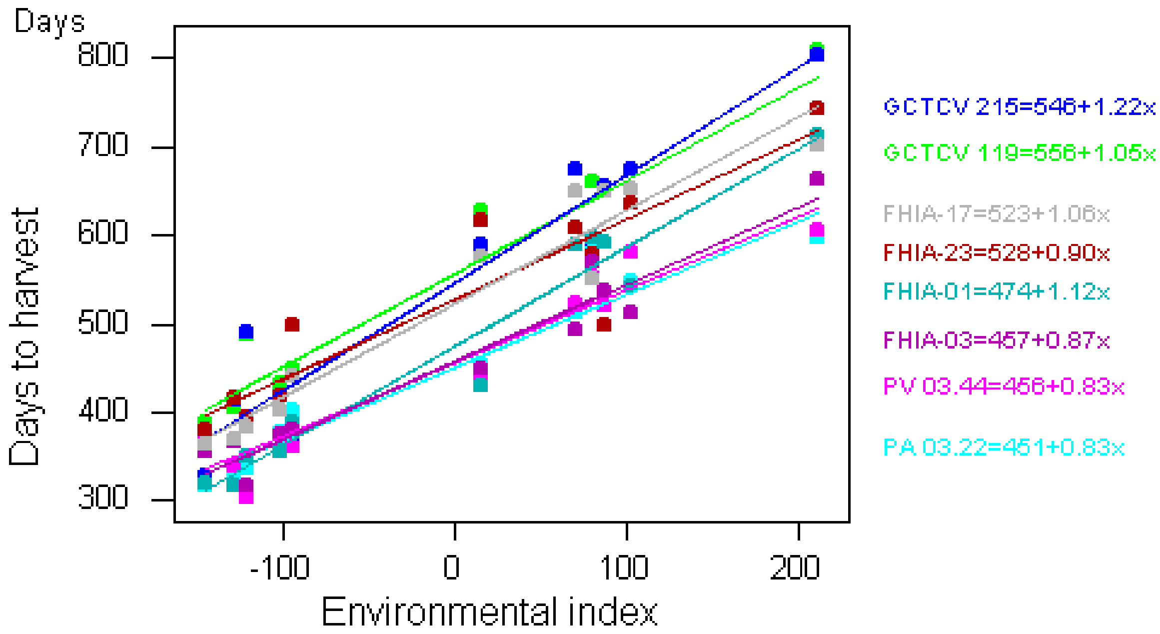


Figure 9b: Regression days to harvest - environmental index. Fusarium trials

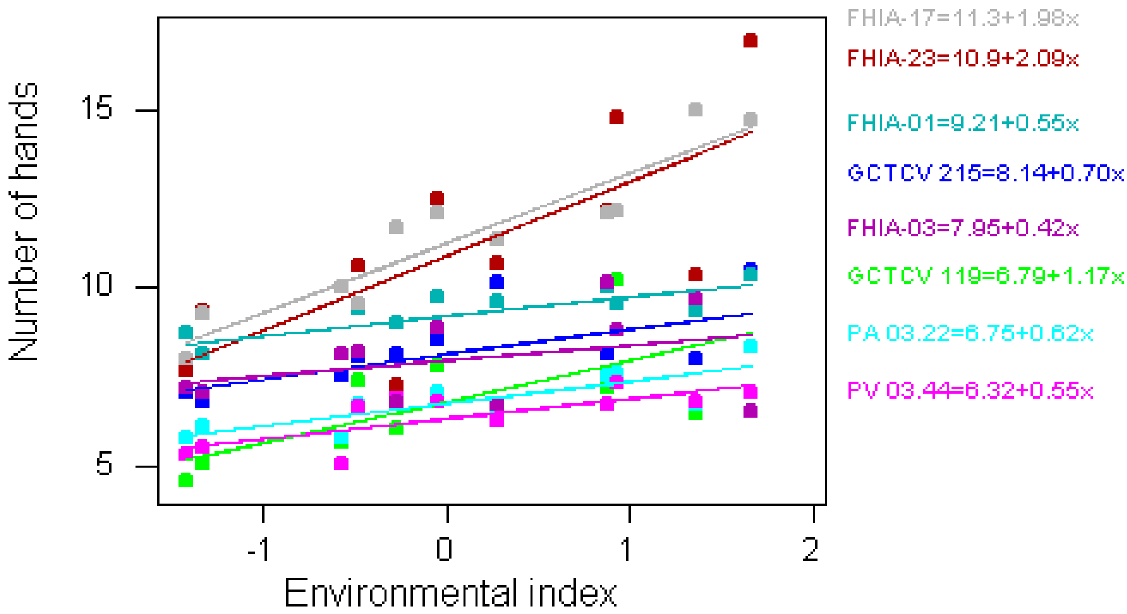


Figure 9c: Regression number of hands - environmental index. Fusarium trials

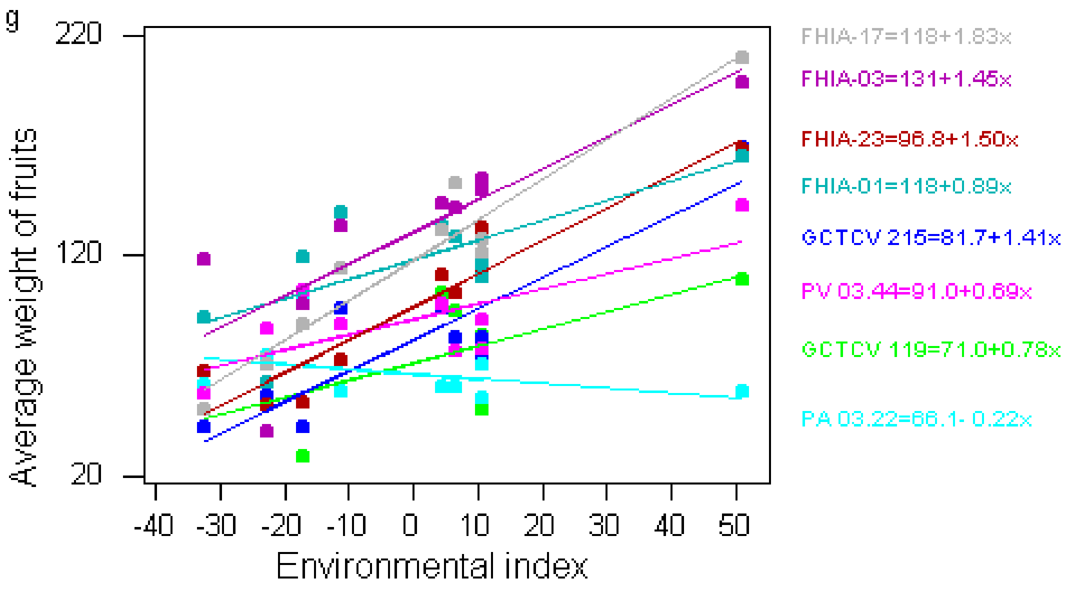


Figure 9d: Regression average weight of fingers - environmental index. Fusarium trials

Landraces

Bluggoe was the genotype with the highest discolouration scores on both types of sites. It had a score of 3.5 on race 1 sites and 4.1 on sites with race 4 indicating high susceptibility to both races of *Foc*. Burro CEMSA, an ABB collected by INIVIT (Jose Manuel Alvarez, pers. comm.) and classified by them as a somaclonal variant of Bluggoe, had less discolouration scores than Bluggoe. It had a general average of 2.8 in sites with race 1 and an average score of 2.9 in sites with race 4. The other genotype that showed susceptibility to both races was Gros Michel with a score of 3.2 for race 1 sites and 3.5 for race 4 sites. Another landrace that showed higher than the general average discolouration scores for both types of sites was Saba. On sites with *Foc* race 1, Saba had a general average of 2.8 and on sites infested with *Foc* race 4 a score of 3.

Some landraces had a very specific reaction to the race of *Foc*, for example Yangambi Km 5 and Pisang Mas. Yangambi had a score of 2.1 which was lower than the general average for sites with race 1 but it had a score of 4.1 well above the average for sites with race 4. The difference, although less marked, was also evident for Pisang Mas. On sites with race 1, Pisang Mas had a score of 2.06 while for sites with race 4 it had a score of 3.5.

Landraces that consistently had scores lower than the average were Cultivar Rose and Pisang Nangka. It should be noted that the Cavendish clone Williams that was included as the race 4 susceptible reference was a dwarf somaclonal variant and therefore data from this clone should not be considered reliable.

Stability of clones

Linear regressions of bunch weight, number of hands and average weight of fruits on the environmental index were performed (Figure 9a-d). For a genotype to be considered agronomically stable, the slope (β) needs to be at least one, meaning that the change in the genotype average changes in the same measure as the environment. The four FHIA hybrids proved to be the most stable genotypes across environments. Moreover, they generally had β values higher than one, which indicated a better than expected performance of the hybrids in the various environments (Table 8). Somaclonal variant GCTCV 119 was also very stable for bunch weight (β= 1.18, $p<0.01$) and number of hands (β= 1.17, $p<0.05$). Somaclonal variant GCTCV 215 was very stable for the average weight of fruits (β= 1.41, $p<0.01$) and had good stability for the number of hands (β= 0.701, $p<0.05$) and for bunch weight (β= 0.710, $p<0.05$).

The case for days to harvest was slightly different as the number of days to harvest greatly depended on the type of climate and local practices. The regression index β is therefore generally close to one and always highly significant (β< 0.01). The strong correlation indices (R^2) between the genotype averages for days to harvest and the environmental indices for this trait corroborate this fact.

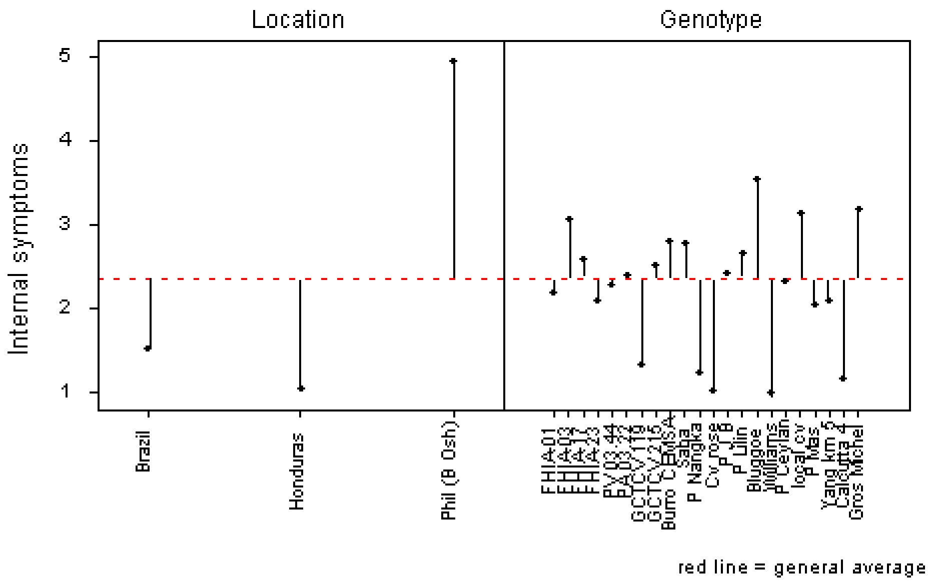


Figure 10: Means for Internal symptoms - *Foc* Race 1

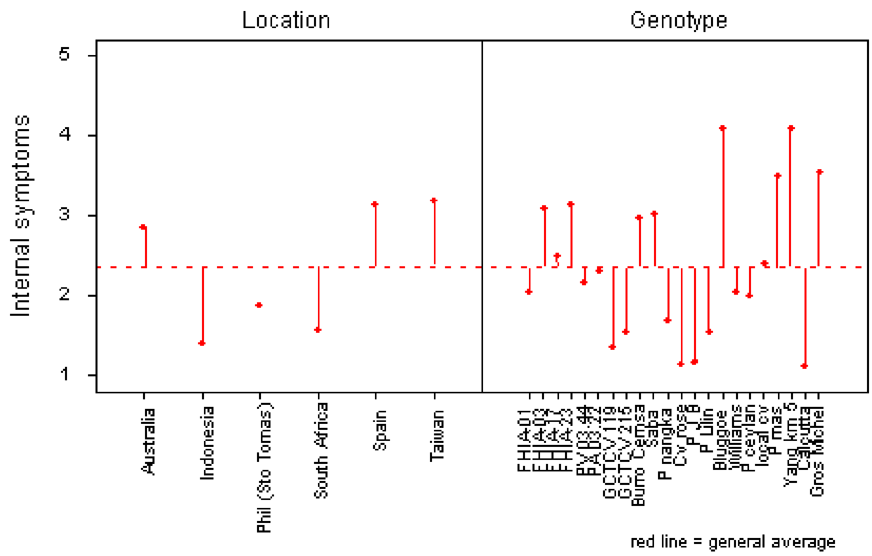


Figure 11: Means for Internal symptoms - *Foc* Race 4

Discussion and conclusions

This is the first study on the agronomic behaviour and pathological response of so many *Musa* cultivars (22 for the Fusarium wilt trials and 12 for the Sigatoka diseases trials) in 21 sites located in 15 countries. The importance of this study is that it has allowed us to estimate not only the yield and productivity or the resistance/tolerance of new improved cultivars in a particular environment but also their stability across environments. As environments change not only across sites but also from year to year within a site, stability in production and in response to disease is an important parameter to consider.

Figures 12 and 13 show the plot of the general average of bunch weight and the infection index at bunch emergence in relation to the slope (β listed in Table 3 and 6) that classifies for stability. In this way it is possible to group the cultivars according to production and stability. A β equal to 1 that was the criteria to classify a cultivar as stable and the general average for bunch weight were used to divide the plot into four quadrants. Considering bunch weight (Figure 12), in the Sigatoka trials, FHIA-23 produced the biggest bunches and showed to be the most stable cultivar. SH 3436-9 also had a very good behaviour (stability and production) across trial sites. Among the landraces, Pisang Ceylan, Saba and Yangambi Km 5 also had good and stable bunch sizes. The local cultivar is a special case since it was a different genotype in every place and therefore cannot be considered in this stability study. It was plotted with the others to remark its above-average bunch weights and the stable range of weight that is normally chosen by farmers. The response to black Sigatoka showed important variations from country to country. Considering the infection index at bunch emergence FHIA-23 was classified as resistant and stable (Figure 13), although Calcutta 4 and Yangambi Km 5 had a strange response to disease: having infection in some places (Tables 4 and 5), they are still grouped with the resistant and stable genotypes Figure 13. The strange results with Calcutta 4 and Yangambi Km 5 in some places might be an indication of the breakdown of resistance to *M. fijiensis* or the presence of a new pathogen with similar symptoms to Sigatoka. These results however could also be an indication of difficulties with symptom observation in some sites. These results indicate that plant resistance/tolerance is influenced by many factors, including management, soil fertility, pathogen pressure, presence of other pathogens and climatic conditions; therefore, it is not possible to generalize the results. It is extremely important to evaluate the genotype under the conditions of interest.

The effects of environmental factors, and their role in yield, are not easy to demonstrate or quantify. Experiments have been carried out to determine how these factors affect yield. For example research carried out at CRBP, Cameroon has demonstrated the influence of black Sigatoka on the bunch weight (J.V. Escalant, pers. comm.). Similarly, using the IMTP results for infection index at bunch emergence and the average fruit weight across sites and genotype, good correlations (Table 11) were found, with an R^2 of –0.71 (p<0.01) if only Cameroon, Costa Rica (1st generation) and Tonga, the first three reference locations are considered, and a correlation of -0.608 (p<0.01) if all locations are considered. This indicates that the number of parameters for which data are collected could be reduced, thus facilitating data collection and management. It would also reduce the need for visual interpretation of symptoms in the field.

In Fusarium wilt trials, Figure 14 plots the bunch weight in relation to the slope (β listed in Table 8) that classifies for stability. FHIA-17 and FHIA-23 were the most stable and best-yielding cultivars across sites followed by FHIA-03. FHIA-01 although with good yields had too much variability from site to site. GCTCV 119 was also classified as stable although its bunch weights were slightly lower than the general average. With respect to the internal symptoms score (Figure 15), the instability of certain cultivars with low symptom scores must be due to the pathogen variability across trial sites. A specific multilocational trial needs to be carried out for each VCG.

The FHIA hybrids were consistently the best-yielding genotypes in these trials. With few exceptions their bunches outweighed bunches produced by all the other improved and local cultivars. They also responded well to careful management and to fertiliser application, as in the case of Costa Rica and Taiwan. In summary the FHIA hybrids performed well under a range of conditions and responded even better when conditions improved. However, as many sites have only provided data for only one cycle it has not been possible to have complete information on the productivity (yield/year) of the hybrids tested. The length of cycle of any new improved cultivar is an essential trait that deserves further study.

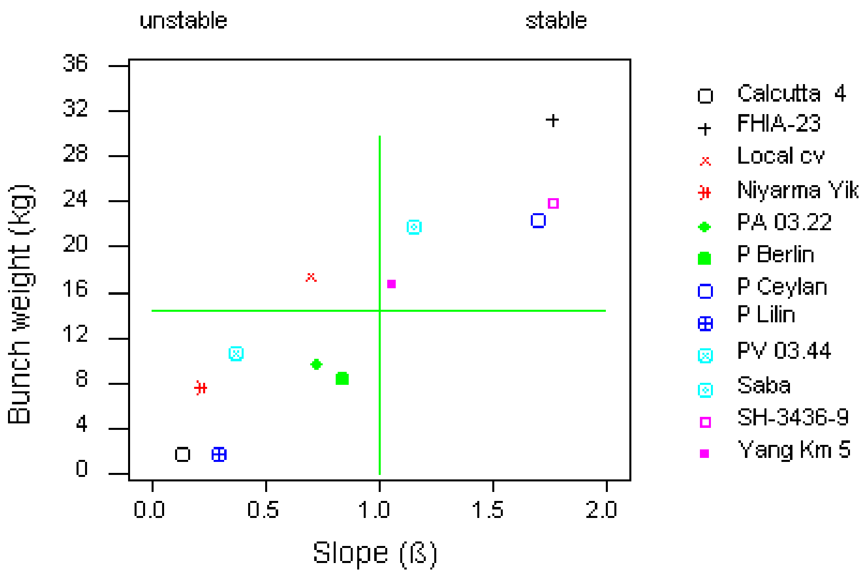


Figure 12: Stability in relation to bunch weight for each genotype in the Sigatoka trials

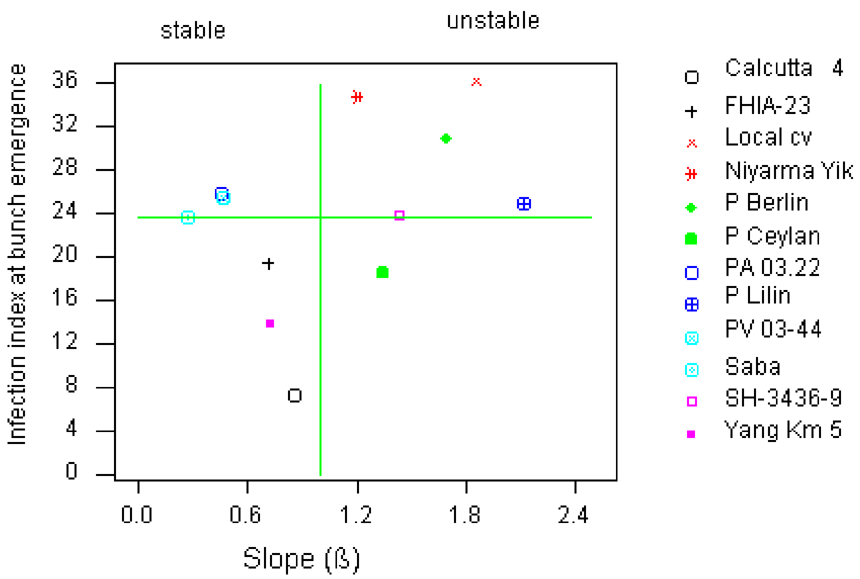


Figure 13: Stability in relation to infection index for each genotype in the Sigatoka trials

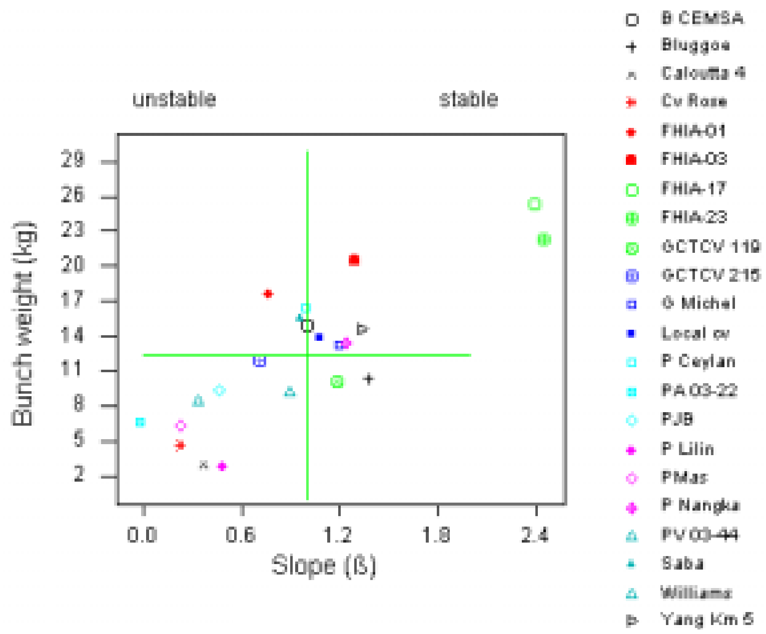


Figure 14: Stability in relation to bunch weight for each genotype in the Fusarium trials

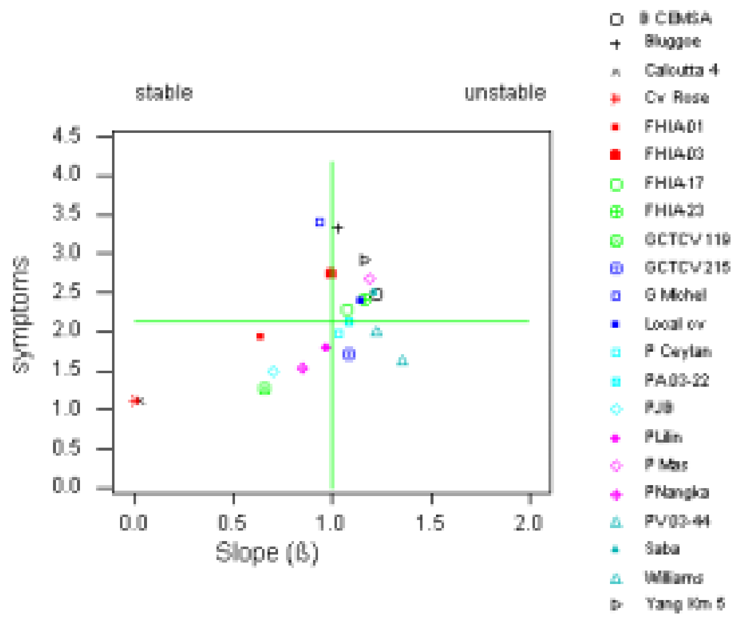


Figure 15: Stability in relation to internal symptoms for each genotype in the Fusarium trials

An improved cultivar that deserves special reference is GCTCV 119, which had the lowest discolouration score for both *Foc* races and good yields under good management.

Yield data were combined with the Fusarium and black Sigatoka reaction data to give an indication of overall and comparative performance of the cultivars in different diseased situations. It is important to stress that resistance alone is not useful. It needs to be combined with good production, acceptable postharvest and organoleptic traits. Improved banana cultivars contribute not only to reducing disease incidence but also to improving food production.

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Table 1. Site details to which plant material and evaluation protocols were sent.

Location and disease present	Latitude	Longitude	Altitude m	Highest temperature °C	Lowest temperature °C	Average temperature °C
Australia; Cudgen - *Foc*	28°16' S	153°33' E	30	39.8	6.2	21.0
Australia; Wamuran - *Foc*	27°28' S	153°02' E	380	45.0	4.0	22.0
Brazil; Cruz das Almas - *Foc*	12°40' S	39°06' W	225	33.4	18.4	24.1
Cameroon; Dschang - YS	4°35' N	9°39' E	1350			
Cameroon; Njombe - BS	4°35' N	9°39' E	80	32.2	22.1	27.1
Colombia; El Agrado, Quindío - YS	4°31' N	75°47' N	1320	28.5	17.2	20.0
Costa Rica; La Rita, Guápiles - BS	10°16' N	83°27' W	125	30.0	18.1	23.2
Cuba; Alquizar Havana Province	23° 8' N	82°22' W	40	--	--	--
Cuba; Santiago de Las Vegas, Villa Clara, Havana Province - *Foc*	23° 8' N	82°22' W	40	--	--	--
Cuba;Santiago de las Vegas, Havanna province	--	--	40	--	--	--
Honduras; La Lima - BS	14° 5' N	87°14' W	31	34.7	23.8	25.4
Honduras; La Lima, Cortes - *Foc*	15°25' N	87°56' W	31	34.7	23.8	25.4
India; Bangalore, Karnataka	13°58' N	78° ' E	890	34.9	13.0	23.8
India; BRS, Kannara, Thrissur	10° 0' N	70° ' E	55	30.9	25.3	20.5
India; Kovvur Andra Pradesh	17° 0' N	81°43' E	6	49.0	17.0	30.1
India; Podavur, Tamil Nadu - BS	10°50' N	74°50' E	90	37.5	18.5	22.5
India; Podavur, Tamil Nadu - *Foc*	10°50' N	74°50' E	90	37.5	18.5	22.5
Indonesia; Aripan Solok, West Sumatra - *Foc*	0° 1' S	100°36' E	415	32.0	18.0	26.5
Indonesia; Deli Serdang, North Sumatra - *Foc*	4° 0' N	99° ' E	14	--	--	--
Indonesia; Lampung-*Foc*	5°03' S	105°41' E	50	36.3	--	--
Malaysia; Kotta Tinggi, Johor - *Foc*	1 °37' N	103°56' E	30	--	--	--
Malaysia; Serdang, Selangor - *Foc*	3° 0' N	101°41' E	60	--	--	--
Nigeria; Abuja - BS	7°20' E	9°16' N	300	34.0	13.0	--
Nigeria; Ibadan - BS	3°54' E	7°26' N	150	34.0	12.0	24.0
Nigeria; Onne - BS	7°10' E	4°46' N	30	32.0	12.0	26.0
Nigeria; Onne - BS	7°10' E	4°46' N	30	32.0	12.0	26.0
South Africa; Hazyview, Eastern Transvaal - *Foc*	25°07' S	31°05' E	722	28.0	10.5	23.3
Spain; Valle de Guerra, Canary Islands - *Foc*	28°31' N	18°22' W	50	26.6	13.0	19.6
Sta Lucia-YS	14° 0' N	61° ' W	50	31.3	21.6	26.8
Taiwan; Chiuju, Pingtung - *Foc*	22°42' N	120°29' E	100	35.0	14.0	22.0
Thailand; Phichit, Phichit Province - *Foc*	16°25' N	100°15' E	40	36.4	17.4	28.4
Thailand; Sawi, Chumphon province - YS	--	--	--	--	--	--
The Phillippines; Davao, Mindanao - BS	7° 5' N	125°36' E	100	34.0	18.5	26.2
The Phillippines; Mepi, Sto Tomas North Davao, Mindanao - *Foc*	7°30' N	125°39' E	39	33.8	20.3	27.0
Tonga; Vaini, Tongatapu - BS	21°10' S	175°10' W	30	32.0	18.0	--
Uganda; Kawanda, Kampala - BS	0°19' N	32°32' E	1210	27.6	15.3	--
Uganda; Mitooma and Buyanrugulu county, Bushenyi district - *Foc*	0°35' S	30°03' E	1200	35.5	12.3	--
Tonga; Vaini, Tongatapu - BS	21°10' S	175°10' W	30	32.0	18.0	--
Uganda; Kawanda, Kampala - BS	0°19' N	32°32' E	1210	27.6	15.3	--
Uganda; Mitooma and Buyanrugulu county, Bushenyi district - *Foc*	0°35' S	30°03' E	1200	35.5	12.3	--

Table 1. Site details to which plant material and evaluation protocols were sent. (Continued)

Location and disease present	Texture	PH	Taxonomy	Drainage	Topography
Australia; Cudgen - *Foc*	Loam	6.0	Vertisols	Good	Hill
Australia; Wamuran - *Foc*	Clay	6.5		Poor	Hill
Brazil; Cruz das Almas - *Foc*	Sandy loam	5.5	Oxisols	Good	Plain
Cameroon; Dschang - YS	Highly organic	6.5	Andi oxisols	Moderate	Plain
Cameroon; Njombe - BS	Highly organic	6.0	Andisols	Good	Plain
Colombia; El Agrado, Quindío - YS	Sandy loam	5.5	Andisols	Good	Plain
Costa Rica; La Rita, Guápiles - BS	Sandy loam	6.0	Andisols	Good	Plain
Cuba; Alquizar Havana Province	Clay	5.0	Oxisol	Good	Plain
Cuba; Villa Clara, Havana Province - *Foc*	Clay	1.0	Oxisols	Good	Plain
Cuba;Santiago de las Vegas, Havanna province	Clay	--	Oxisol	Good	Plain
Honduras; La Lima - BS	Loam	7.0	Entisols	Good	Valley
Honduras; La Lima, Cortes - *Foc*	Loam	7.0	Entisols	Good	Valley
India; Bangalore, Karnataka	Sandy loam	7.0	Alfisol	Good	Plain
India; BRS, Kannara, Thrissur	Sandy loam	7.5	Alfisol	Moderate	Plain
India; Kovvur Andra Pradesh	Clay loam	8.2	Vertisols	Good	Plain
India; Podavur, Tamil Nadu - BS	Clay loam	8.0	Vertic Ustropepts	Moderate	Plain
India; Podavur, Tamil Nadu - *Foc*	Clay loam	8.0	Vertic Ustropepts	Moderate	Plain
Indonesia; Aripan Solok, West Sumatra - *Foc*	Clay	5.5	Alvisols	Good	Hill
Indonesia; Deli Serdang, North Sumatra - *Foc*	Gravy sandy	5.5	Ultisols	Poor	Plain
Indonesia; Lampung-*Foc*	Sandy clay loam	5.7	Ultisols	Moderate	Plateau
Malaysia; Kotta Tinggi, Johor - *Foc*	Clay loam	5.2	Ultisols	Moderate	Upland
Malaysia; Serdang, Selangor - *Foc*	Sandy loam	4.5	Entisols	Moderate	Upland
Nigeria; Abuja - BS	Coarse loam	--	Ferric Luvisols	Good	Plain
Nigeria; Ibadan - BS	Coarse loam	--	Ferric Luvisols	Good	Plain
Nigeria; Onne - BS	Coarse loam	4.3	Thionic Fluvisols	Good	Plain
Nigeria; Onne - BS	Coarse loam	4.3	Thionic Fluvisols	Good	Plain
South Africa; Hazyview, Eastern Transvaal - *Foc*	Clay loam	5.1	Oxisols	Good	Hill
Spain; Valle de Guerra, Tenerife, Canary Islands - *Foc*	Clay loam	6.5	Hallosyte Illtie	Poor	Valley
Sta Lucia-YS	Clay loam	6.1	Inceptisols	Moderate	Bassin
Taiwan; Chiuju, Pingtung - *Foc*	Loam	5.2		Moderate	Plain
Thailand; Phichit, Phichit Province - *Foc*	Clay loam	5.5			Plain
Thailand; Sawi, Chumphon province - YS					
The Phillippines; Davao, Mindanao - BS	Clay loam	5.4	Ultisols	Moderate	Plain
The Phillippines; Mepi Sto Tomas North Davao, Mindanao - *Foc*	Clay loam	6.7	Inceptisols	Good	Plain
Tonga; Vaini, Tongatapu - BS	Clay loam	6.5	Mollisols	Good	Plain
Uganda; Kawanda, Kampala - BS	Coarse loam	5.5	Oxisols	Good	Hill
Uganda; Mitooma and Buyanrugulu county, Bushenyi district Western - *Foc*	Clay loam	5.6	Andisols	Good	Upland

Table 1. Site details to which plant material and evaluation protocols were sent. (Continued)

Location and disease present	Highest humidity	Lowest humidity	Average humidity	Number of days rain	Rainfall mm	Water availability	Nb of hours with 90% humidity
Australia; Cudgen - *Foc*	--	--	--	173	1875	Both/alternate	--
Australia; Wamuran - *Foc*	--	--	--	145	915	Both/alternate	--
Brazil; Cruz das Almas - *Foc*	--	--	--	--	1083	Irrigated	--
Cameroon; Dschang - YS	--	--	--	--	--	Rainfed/drought	--
Cameroon; Njombe - BS	100.0	32.0	72.0	161	2086	Both/alternate	303
Colombia; El Agrado, Quindío - YS	80.0	70.0	76.0	217	2100	Rainfed	0
Costa Rica; La Rita, Guápiles - BS	97.9	61.5	86.5	235	3600-4000	Rainfed	93.62/week
Cuba; Alquizar Havana Province	--	--	--	--	--	Irrigated	--
Cuba; Santiago de Las Vegas, Villa Clara, Havana Province - *Foc*	--	--	--	--	--	Irrigated	--
Cuba; Santiago de las Vegas, Havana province	--	--	--	--	--	--	--
Honduras; La Lima - BS	84.1	79.3	74.5	109	1015	Rainfed	--
Honduras; La Lima, Cortes - *Foc*	84.1	79.3	74.5	109	1015	Rainfed	--
India; Bangalore, Karnataka	78.3	30.2	60.31	85	931.5	Irrigated	--
India; BRS, Kannara, Thrissur	95.7	58.3	66.6	125	2631.5	Irrigated	--
India; Kovvur Andra Pradesh	84.6	64.2	60.29	80	1508.4	Irrigated	--
India; Podavur, Tamil Nadu - BS	90.0	53.4	72.5	53	556.7	Irrigated	--
India; Podavur, Tamil Nadu - *Foc*	90.0	53.4	72.5	53	556.7	Irrigated	--
Indonesia; Aripan Solok, West Sumatra - *Foc*	100.0	67.0	85.0	151	1358	Rainfed	--
Indonesia; Deli Serdang, North Sumatra - *Foc*	98.5	87.1	94.57	153	2745	Both/alternate	--
Indonesia; Lampung - *Foc*	98.0	52.0	87	115	1560	Both/alternate	--
Malaysia; Kotta Tinggi, Johor - *Foc*	--	--	--	--	--	Irrigated	--
Malaysia; Serdang, Selangor - *Foc*	--	--	--	--	--	Both	--
Nigeria; Abuja - BS	--	--	--	--	1302	Both/alternate	--
Nigeria; Ibadan - BS	--	--	--	--	1252	Rainfed	--
Nigeria; Onne - BS	--	--	--	--	2400	Rainfed	--
Nigeria; Onne - BS	--	--	--	--	2400	Rainfed	--
South Africa; Hazyview, Eastern Transvaal - *Foc*	99.3	12.8	62.5	96	963	Both/alternate	--
Spain; Valle de Guerra, Tenerife, Canary Islands - *Foc*	91.0	63.0	74	59	364	Irrigated	--
Sta Lucia -YS	79.0	71.0	76	201	1724	Rainfed	--
Taiwan; Chiuju, Pingtung - *Foc*	--	--	--	--	1600	Both/Alternate	--
Thailand; Phichit, Phichit Province - *Foc*	97.0	32.0	73.3	107	1017	--	--
Thailand; Sawi, Chumphon province - YS	--	--	--	--	--	--	--
The Phillippines; Davao, Mindanao - BS	98.0	64.0	82	200	5049	Irrigated	--
The Phillippines; Mepi Sto Tomas North Davao, Mindanao - *Foc*	--	--	--	--	6416	Rainfed	--
Tonga; Vaini, Tongatapu - BS	80.0	60.0	--	--	1775	Rainfed	--
Uganda; Kawanda, Kampala - BS	--	--	76.3	--	1250	--	--
Uganda; Mitooma and Buyanrugulu county, Bushenyi district Western - *Foc*	--	--	--	--	--	Rainfed	--

Table 1. Site details to which plant material and evaluation protocols were sent. (Continued)

Location and disease present	Institute	Planting date	Plant spacing	Experimental design	Number of repetitions
Australia; Cudgen -*Foc*	QDPI	24/11/95	3 x 3	CRD	20
Australia; Wamuran - *Foc*	QDPI	14/11/95	3 x 3	CRD	20
Brazil; Cruz das Almas - *Foc*	EMBRAPA	26/03/96	3 x 2	CRD	20
Cameroon; Dschang - YS	CRBP	08/08/96	3 x 2.5	CRBD	5
Cameroon; Njombe - BS	CRBP	19/10/95	3 x 2.5	CRBD	5
Colombia; El Agrado, Quindío - YS	CORPOICA	19/03/97	3 x 2.5	CRBD	5
Costa Rica; La Rita, Guápiles - BS	CORBANA	12/02/96	2.5 x 3	CRBD	5
Cuba; Alquizar Havana Province	Min. Agr. Cuba	--			
Cuba; Santiago de Las Vegas, Villa Clara, Havana Province - *Foc*	Min. Agr. Cuba	12/02/97	3 x 3	CRD	22
Cuba; Santiago de las Vegas, Havana province	Min. Agr. Cuba	--			
Honduras; La Lima - BS	FHIA	12/07/96	2.5 x 2.5	CRBD	5
Honduras; La Lima, Cortes - *Foc*	FHIA	07/06/96	3 x 2	CRBD	18
India; Bangalore, Karnataka	NRCB	--	--	--	--
India; BRS, Kannara, Thrissur	NRCB	--	--	--	--
India; Kovvur Andra Pradesh	NRCB	--	--	--	--
India; Podavur, Tamil Nadu - BS	NRCB	12/08/96	3 x 2	CRBD	5
India; Podavur, Tamil Nadu - *Foc*	NRCB	10/05/96	3 x 3	CRD	20
Indonesia; Aripan Solok, West Sumatra - *Foc*	RIF	15/04/96	3 x 2	CRD	10
Indonesia; Deli Serdang, North Sumatra - *Foc*	RIF	13/03/96	3.5 x 2	CRD	20
Indonesia; Lampung - *Foc*	RIF	30/12/97	3 x 2	CRD	20
Malaysia; Kotta Tinggi, Johor - *Foc*	MARDI	25/04/96	3 x 2	CRD	20
Malaysia; Serdang, Selangor - *Foc*	MARDI	18/12/95	3 x 2	CRD	20
Nigeria; Abuja - BS	IITA	08/08/95	3 x 2	Lattice	5
Nigeria; Ibadan - BS	IITA	14/08/95	3 x 2	Lattice	5
Nigeria; Onne - BS	IITA	20/06/95	3 x 2	Lattice	5
Nigeria; Onne - BS	IITA	19/06/95	3 x 2	Lattice	5
South Africa; Hazyview, Eastern Transvaal - *Foc*	ITSC/ARC	10/08/95	2 x 1 x 5	CRD	20
Spain; Valle de Guerra, Tenerife, Canary Islands - *Foc*	ICIA	02/01/96	3 x 3	CRD	20
Sta Lucia -YS	WIBDECO	29/01/96	3 x 3	CRBD	5
Taiwan; Chiuju, Pingtung - *Foc*	TBRI	23/05/96	1.5 x 2.1	CRD	14
Thailand; Phichit, Phichit Province - *Foc*	HRI	--	--	--	--
Thailand; Sawi, Chumphon province - YS	HRI	--	--	--	--
The Phillippines; Davao, Mindanao - BS	BPI	20/06/96	2,5 x 2,5	CRBD	5
The Phillippines; Mepi Sto Tomas North Davao, Mindanao - *Foc*	BPI	29/12/95	2.5 x 2.5	CRBD	5
Tonga; Vaini, Tongatapu - BS	MAFF	09/01/96	2,5 x 3	CRBD	5
Uganda; Kawanda, Kampala - BS	NARO	15/12/95	3 x 3	CRBD	5
Uganda; Mitooma and Buyanrugulu county, Bushenyi district Western - *Foc*	NARO	30/11/95	3 x 3	CRD	5

BS: Black Sigatoka YS: Yellow Sigatoka *Foc*: *Fusarium oxysporum* f.sp. *cubense* CRD: Complete randomised design
CRBD: Complete randomised block design -- Not available or not applicable

Table 2. Average and coefficient of variation (Cv) of the main agronomic traits classified by genotype and location. IMTP Sigatoka diseases sites.

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
FHIA-23	Philippines	15.8	42.58	471.6	3.45	8.2	30.45	117.2	38.88
	Cameroon	39.3	9.36	369.5	2.52	13.2	6.3	246.5	9.79
	Costa Rica 1	37.5	10.45	409.0	4.29	13.2	4.3	244.3	4.21
	Costa Rica 2	36.6	11.20	*	*	15.0	9.89	281.7	12.54
	Honduras	30.4	15.24	512.4	8.97	12.9	4.23	219.4	5.23
	Tonga	36.5	*	432.0	*	16.0	*	294.0	*
	Uganda	23.8	33.96	651.0	16.62	11.8	25.13	125.5	36.26
Average		31.4		474.2		12.9		218.3	
PV 03.44	Philippines	9.7	13.58	398.9	4.92	6.4	6.54	89.8	6.06
	Cameroon	12.9	17.51	268.8	7.36	7.4	7.78	119.8	12.41
	Costa Rica 1	7.6	17.12	329.8	2.40	7.4	6.68	107.2	11.19
	Costa Rica 2	12.7	7.58	*	*	7.8	6.11	125.3	7.59
	Honduras	10.8	10.49	387.8	18.58	6.0	4.42	77.3	9.12
	Uganda	8.5	15.11	435.7	4.13	6.2	3.43	89.3	13.50
	Tonga	11.3	*	380.0	*	7.0	*	98.0	*
Average		10.5		366.8		6.8		100.9	
PA 03.22	Philippines	5.5	38.17	354.0	2.98	6.3	16.56	77.9	30.32
	Cameroon	10.3	20.76	266.8	7.35	7.4	8.3	116.4	13.34
	Costa Rica 1	8.9	21.49	343.5	3.06	7.1	3.29	113.3	3.68
	Costa Rica 2	18.4	14.03	*	*	7.9	5.04	132.6	10.61
	Honduras	7.1	17.70	349.4	12.39	6.2	8.11	72.7	13.24
	Uganda	7.9	13.07	394.4	7.90	6.9	8.26	89.0	13.66
	Tonga	9.3	*	396.0	*	6.0	*	88.0	*
Average		9.6		350.6		6.8		98.5	
SH 3436-9	Philippines	10.4	35.97	432.2	13.61	7.1	9.68	94.9	15.74
	Cameroon	26.1	7.12	302.1	6.08	9.8	4.17	147.7	4.68
	Costa Rica 1	27.3	17.48	375.0	9.14	11.4	4.41	190.7	7.70
	Costa Rica 2	34.2	7.20	*	*	12.6	11.13	222.5	8.57
	Honduras	25.6	11.42	450.1	7.10	11.6	11.69	179.9	8.52
	Tonga	28.8	*	417.0	*	10.0	*	177.0	*
	Uganda	15.6	26.41	544.7	8.39	8.9	4.66	124.8	19.19
Average		24.0		420.1		10.2		162.5	
Yang. Km 5	Philippines	8.0	20.73	407.6	5.57	6.6	6.29	106.9	10.80
	Cameroon	21.3	5.31	289.4	2.25	8.2	4.88	172.8	6.97
	Costa Rica 1	16.0	19.92	467.6	10.46	7.8	14.86	169.9	15.66
	Costa Rica 2	23.0	42.09	*	*	9.8	26.17	216.9	28.53
	Honduras	17.2	5.12	452.4	11.69	7.8	2.14	147.9	6.65
	Tonga	16.1	*	427.0	*	9.0	*	196.0	*
	Uganda	15.1	20.88	531.2	8.88	9.1	10.74	165.2	21.89
Average		16.6		429.2		8.3		167.9	

Table 2. Average and coefficient of variation (Cv) of the main agronomic traits classified by genotype and location. IMTP Sigatoka diseases sites. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Niyarma-Yik	Philippines	4.6	18.84	415.5	8.69	5.7	8.32	80.3	30.69
	Cameroon	6.4	6.66	250.7	9.26	6.2	8.69	85.3	5.33
	Costa Rica 1	6.6	11.96	269.3	1.23	6.5	7.74	90.3	5.15
	Costa Rica 2	7.8	11.68	*	*	6.4	5.4	86.0	7.29
	Honduras	9.5	14.65	429.9	6.46	7.5	20	101.4	26.07
	Tonga	8.2	*	362.0	*	7.0	*	83.0	*
	Uganda	6.7	22.06	426.1	9.90	7.3	13.57	86.0	12.83
Average		7.5		347.6		6.8		88.6	
Saba	Philippines	20.5	5.59	355.5	8.14	6.7	5.29	97.7	7.54
	Cameroon	28.7	10.15	285.5	0.83	8.4	6.28	123.7	5.94
	Costa Rica 1	21.8	16.92	372.0	3.50	7.3	9.09	106.6	13.00
	Costa Rica 2	30.6	5.38	*	*	7.6	7.26	115.1	7.94
	Honduras	22.4	6.30	379.8	5.89	5.9	10.68	76.9	12.81
	Tonga	17.1	*	414.0	*	6.0	*	67.0	*
	Uganda	11.2	40.37	449.4	4.55	5.3	22.78	66.5	40.75
Average		21.7		376.0		6.7		93.3	
P. Ceylan	Philippines	13.9	19.15	366.7	4.98	9.7	2.22	158.3	11.68
	Cameroon	33.7	9.70	285.6	2.11	12.3	7.21	228.7	7.43
	Costa Rica 1	20.0	6.81	359.0	1.49	11.3	2.94	195.7	12.85
	Costa Rica 2	31.4	6.55	*	*	14.5	3.15	260.9	3.20
	Honduras	22.7	10.60	408.7	9.57	11.1	3.51	182.5	7.42
	Uganda	14.3	43.86	516.1	6.03	9.4	2.53	139.3	10.82
	Tonga	20.3	*	424.0	*	12.0	*	191.0	*
Average		22.3		393.3		11.4		193.7	
Calcutta 4	Philippines	0.4	55.09	399.4	8.39	4.7	14.44	51.4	27.13
	Cameroon	2.8	17.72	249.8	4.94	6.9	11.09	118.3	7.86
	Costa Rica 1	1.5	16.19	341.8	1.25	6.5	6.85	109.4	13.62
	Costa Rica 2	1.8	16.51	*	*	7.8	11.55	156.8	19.61
	Uganda	1.2	25.66	374.0	2.82	7.4	25.88	142.8	12.18
	Tonga	*	*	*	*	*	*	*	*
Average		1.5		341.2		6.6		115.7	
P. Lilin	Philippines	0.5	21.48	318.5	12.86	3.0	20.84	43.1	66.17
	Cameroon	*	*	*	*	*	*	*	*
	Costa Rica 1	1.0	43.39	259.0	*	4.5	14.99	50.5	17.15
	Costa Rica 2	4.3	59.69	*	*	6.6	28.15	99.0	41.59
	Honduras	1.1	79.63	348.1	11.11	3.4	14.99	35.9	26.63
	Tonga	*	*	*	*	*	*	*	*
	Uganda	0.6	86.60	464.5	42.47	5.0	*	68.0	*
Average		1.5		347.5		4.5		59.3	

Table 2. Average and coefficient of variation (Cv) of the main agronomic traits classified by genotype and location. IMTP Sigatoka diseases sites. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
P. Berlin	Philippines	4.0	38.07	368.6	13.71	6.6	8.3	86.5	30.63
	Cameroon	10.9	13.70	224.4	6.10	7.8	7.32	133.3	11.68
	Costa Rica 1	9.4	10.21	270.6	1.44	7.6	8.13	134.7	4.94
	Costa Rica 2	15	17.38	*	*	9.5	9.92	188.3	13.39
	Honduras	9.4	6.91	381.8	12.31	7.3	5.87	112.5	13.43
	Uganda	3.5	42.63	445.7	5.03	6.1	15.25	73.4	17.20
	Tonga	5.3	*	357.0	*	7.0	*	91.0	*
Average		8.2		341.3		7.4		117.1	
Local cultivar	Philippines	10.4	18.84	454.3	7.71	7.3	6.49	108.7	32.08
	Cameroon	15.9	17.37	292.2	10.92	6.7	7.97	88.9	11.06
	Costa Rica 1	12.4	12.13	331.6	4.93	9.3	5.43	159.5	5.49
	Costa Rica 2	20.6	10.08	*	*	10.3	1.06	180.2	4.64
	Honduras	22.1	7.90	470.0	8.73	9.7	2.66	148.6	3.21
	Uganda	15.3	4.49	504.6	4.84	7.3	6.43	106.9	9.90
	Tonga	22.7	5.31	365.7	27.05	10.1	3.82	172.3	6.14
Average		17.0		403.0		8.6		137.8	

Costa Rica 1: data from plant crop Costa Rica 2: data from ratoon * : missing data

Table 3. Regression of four important agronomic traits on the environmental index for the Sigatoka trials.

Genotype	Number of hands				Average weight of fruits (g)			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Calcutta 4	6.7	0.83	0.097	65.5	13.6	0.19	0.352	28.7
FHIA-23	12.9	2.23	0.009	77.1	136.4	0.428	0.595	6.1
Local cultivar	8.5	0.83	0.221	34.4	118.4	1.99	0.009	85.1
Niyarma-Yik	6.7	0.17	0.589	6.2	74.5	0.66	0.025	66.8
Pisang Berlin	7.4	0.92	0.031	63.8	60.2	0.52	0.179	32.8
Pisang Ceylan	11.6	1.63	0.003	85.1	106.6	0.88	0.025	66.8
Pisang Lilin	4.7	1.01	0.089	67.3	22.1	0.25	0.367	27.2
PA 03.22	6.9	0.46	0.082	48.5	86.3	0.76	0.106	43.7
PV 03.44	6.8	0.51	0.067	52.2	95.7	0.90	0.030	64.5
Saba	6.7	0.445	0.411	13.9	222.0	1.20	0.162	35.0
SH 3436-9	10.3	1.64	0.011	75.4	131.5	1.09	0.034	62.7
Williams	---	--	--	--	--	--	--	--
Yangambi Km 5	8.4	0.82	0.056	55.0	89.6	0.90	0.014	73.0

Genotype	Bunch weight (kg)				Days to harvest			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Calcutta 4	1.6	0.14	0.064	73.3	347	0.633	0.191	65.5
FHIA-23	31.4	1.77	0.014	73.5	473	1.37	0.009	84.4
Local cultivar	16.3	0.704	0.114	50.4	412	1.20	0.009	92.5
Niyarma-Yik	7.1	0.222	0.153	36.2	358	1.08	0.016	79.8
Pisang Berlin	8.2	0.843	0.016	71.9	340	1.18	0.000	97.6
Pisang Ceylan	22.3	1.700	0.003	86.2	392	1.09	0.004	90.3
Pisang Lilin	1.8	0.296	0.063	73.7	309	1.55	0.010	98.0
PA 03.22	9.6	0.736	0.056	55.1	350	0.606	0.026	74.4
PV 03.44	10.5	0.369	0.042	59.7	366	0.861	0.001	95.8
Saba	21.8	1.160	0.058	54.7	375	0.745	0.015	80.5
SH 3436-9	24.0	1.770	0.004	83.4	419	1.19	0.000	98.4
Williams	---	--	--	--	--	--	--	--
Yangambi Km 5	16.7	1.060	0.003	85.1	428	1.02	0.032	72.5

Table 4. Infection index average and coefficient of variation for black Sigatoka at three evaluation times.

Genotype	Location	Infection index[a] - Coefficient of variation[b]		
		Six months after planting	At bunch emergence	At harvest
FHIA-23				
	Cameroon	6.79[a]	6.27	14.56
		3.88[b]	2.16	3.45
	Costa Rica 1	35.27	18.36	46.17
		8.33	2.34	6.13
	Costa Rica 2	*	21.79	45.99
		*	2.97	4.23
	Honduras	27.29	25.80	71.57
		1.88	6.56	21.49
	Philippines	20.33	24.97	46.64
		4.02	4.77	4.48
	Tonga	16.90	6.10	12.10
		*	*	*
Average		21.31	17.6	39.50
PV 03.44				
	Cameroon	24.68	24.27	86.45
		2.67	1.18	1.94
	Costa Rica 1	38.76	36.12	98.51
		2.10	3.36	2.13
	Costa Rica 2	*	25.72	83.90
		*	2.37	5.73
	Honduras	26.12	17.30	56.62
		1.53	5.18	5.91
	Philippines	16.11	23.93	40.22
		4.42	5.01	5.44
	Tonga	21.70	29.90	81.50
		*	*	*
Average		25.47	26.22	74.53
PA 03.22				
	Cameroon	23.40	23.58	93.34
		2.59	1.66	4.40
	Costa Rica 1	37.53	34.39	97.91
		3.93	2.79	4.16
	Costa Rica 2	*	24.18	76.63
		*	5.08	10.61
	Honduras	22.26	19.22	65.52
		4.37	3.51	8.33
	Philippines	21.37	27.30	52.49
		11.53	11.17	2.38
	Tonga	21.60	34.80	98.40
		*	*	*
Average		25.23	27.29	80.71
SH 3436-9				
	Cameroon	8.14	9.36	27.94
		3.60	1.57	5.19
	Costa Rica 1	43.06	24.61	61.02
		7.17	3.72	2.26
	Costa Rica 2	*	24.46	57.43
		*	2.87	4.51
	Honduras	21.55	16.78	70.35
		3.69	4.41	13.61
	Philippines	25.00	40.25	52.38
		3.29	26.51	20.23
	Tonga	17.6	13.50	18.30
		*	*	*
Average		23.07	21.9	47.90

[a]: Infection Index; [b]: Coefficient of variation; *: missing data

Table 4. Infection index average and coefficient of variation for black Sigatoka at three evaluation times. (Continued)

Genotype	Location	Infection index[a] - Coefficient of variation[b]		
		Six months after planting	At bunch emergence	At harvest
Yang. Km 5				
	Cameroon	0.00	0.00	0.00
		0.00	0.00	0.00
	Costa Rica 1	37.67	18.80	51.45
		7.22	3.39	12.43
	Costa Rica 2	*	24.37	50.47
		*	6.56	17.07
	Honduras	18.30	13.12	26.66
		2.81	1.55	4.79
	Philippines	6.05	12.71	27.68
		3.63	1.97	11.29
	Tonga	18.90	20.00	17.40
		*	*	*
Average		16.18	14.9	28.94
Saba				
	Cameroon	21.65	20.28	56.25
		1.17	1.20	4.52
	Costa Rica 1	37.33	32.26	73.73
		2.84	2.87	6.73
	Costa Rica 2	*	28.69	66.42
		*	4.34	2.62
	Honduras	30.51	20.70	31.55
		1.51	3.50	11.98
	Philippines	12.17	15.71	22.79
		1.58	2.33	6.07
	Tonga	14.80	21.50	35.10
		*	*	*
Average		23.29	23.2	47.64
Pisang Ceylan				
	Cameroon	4.32	2.33	11.10
		2.02	0.92	1.72
	Costa Rica 1	36.32	28.73	50.45
		10.13	2.08	4.57
	Costa Rica 2	*	21.96	38.71
		*	3.27	5.47
	Honduras	25.50	14.17	26.73
		3.58	2.08	6.68
	Philippines	22.53	25.68	36.01
		4.81	3.20	7.19
	Tonga	20.10	19.00	22.00
		*	*	*
Average		21.75	18.6	30.83
Calcutta 4				
	Cameroon	0.00	0.00	0.00
		0.00	0.00	0.00
	Costa Rica 1	19.76	10.62	18.36
		13.97	4.66	11.90
	Costa Rica 2	*	3.38	11.72
		*	2.22	2.76
	Honduras	*	*	*
		*	*	*
	Philippines	7.54	14.83	34.52
		1.78	4.70	9.40
	Tonga	2.50	1.80	<1
		*	*	*
Average		7.45	6.5	13.1

[a]: Infection Index; [b]: Coefficient of variation; *: missing data

Table 4. Infection index average and coefficient of variation for black Sigatoka at three evaluation times. (Continued)

Genotype	Location	Infection index[a] - Coefficient of variation[b]		
		Six months after planting	At bunch emergence	At harvest
Pisang Lilin				
	Cameroon	*	*	*
		*	*	*
	Costa Rica 1	45.51	41.66	100.00
		5.22	*	*
	Costa Rica 2	*	17.29	65.65
		*	4.69	8.24
	Honduras	12.17	14.13	85.00
		6.29	5.38	29.30
	Philippines	33.94	36.73	53.54
		6.82	9.27	3.39
	Tonga	*	*	*
		*	*	*
Average		30.54	24.8	76.04
Pisang Berlin				
	Cameroon	16.19	16.42	27.88
		2.93	2.28	2.18
	Costa Rica 1	50.20	41.63	60.130
		4.79	3.91	5.17
	Costa Rica 2	*	32.66	46.96
		*	2.39	3.46
	Honduras	37.53	18.03	28.22
		5.39	5.65	4.45
	Philippines	33.97	42.14	43.17
		4.92	9.59	9.29
	Tonga	18.10	22.70	26.3
		*	*	*
Average		31.19	24.8	38.77
Niyarma Yik				
	Cameroon	36.15	27.90	64.20
		2.56	2.06	8.09
	Costa Rica 1	50.23	37.05	84.30
		3.67	3.43	4.61
	Costa Rica 2	*	33.79	76.60
		*	4.85	9.41
	Honduras	26.80	22.22	44.43
		2.52	3.72	6.63
	Philippines	45.25	50.18	67.67
		9.33	2.00	8.87
	Tonga	34.40	29.50	39.00
		*	*	*
Average		38.56	34.15	62.70
Local cultivar				
	Cameroon	26.81	24.47	86.57
		1.80	3.42	5.61
	Costa Rica 1	57.34	45.62	100.00
		1.84	4.70	*
	Costa Rica 2	*	36.52	99.72
		*	4.29	0.62
	Honduras	21.38	17.73	50.79
		1.70	3.93	17.73
	Philippines	46.66	54.22	76.13
		4.63	2.27	5.92
	Tonga	31.20	30.00	97.20
		*	*	*
Average		36.67	35.4	85.06

[a]: Infection Index; [b]: Coefficient of variation; *: missing data

Table 5. Average and coefficient of variation (Cv) of the disease development time (DDT) in days and youngest leaf spotted (YLS). IMTP Phase II.

Genotype	Location	DDT	DDT	YLS	YLS
		Avg	*Cv*	*Avg*	*Cv*
FHIA-23	Cameroon	124.97	14.42	10.46	20.74
	Costa Rica	63.06	28.01	7.76	9.06
	Honduras	44.79	26.90	5.12	25.33
	Philippines	91.93	24.89	9.93	23.24
	Tonga	126.31	9.18	11.33	9.63
	Uganda 1	103.96	16.53	7.04	20.40
	Uganda 2	135.31	16.33	8.50	9.84
Average		93.35		7.95	
PV 03.44	Cameroon	72.44	17.97	5.36	51.32
	Costa Rica	57.95	27.11	8.29	7.27
	Honduras	73.42	38.73	6.39	36.16
	Philippines	78.33	21.23	9.75	31.73
	Tonga	62.97	5.41	6.53	3.66
	Uganda 1	87.09	22.85	4.42	45.19
	Uganda 2	84.33	25.48	5.87	26.85
Average		71.92		6.29	
PA 03.22	Cameroon	75.82	19.85	5.04	53.06
	Costa Rica	41.33	27.21	8.18	10.30
	Honduras	81.51	36.05	6.26	37.25
	Philippines	74.71	28.46	9.19	21.27
	Tonga	61.76	4.24	6.57	5.37
	Uganda 1	81.90	21.38	3.75	48.56
	Uganda 2	81.00	34.09	5.60	27.09
Average		70.47		6.32	
SH 3436-9	Cameroon	110.85	16.00	9.16	33.08
	Costa Rica	57.17	35.58	7.37	10.51
	Honduras	49.34	30.97	5.62	25.50
	Philippines	70.59	28.49	10.17	23.19
	Tonga	135.99	12.17	11.08	6.33
	Uganda 1	93.46	18.21	6.41	31.75
	Uganda 2	125.61	20.63	7.35	25.93
Average		74.96		7.65	
Yang. Km 5	Cameroon	0.00	0.00	0.00	0.00
	Costa Rica	58.73	32.46	7.88	7.22
	Honduras	78.05	30.01	7.65	26.64
	Philippines	75.50	27.50	9.50	33.28
	Tonga	107.262	9.67	11.20	4.97
	Uganda 1	106.86	20.91	7.16	29.81
	Uganda 2	*	*	6.00	0.00
Average		66.91		6.90	
Saba	Cameroon	105.65	14.60	8.16	38.85
	Costa Rica	53.38	35.45	8.00	13.41
	Honduras	85.38	28.18	7.78	25.96
	Philippines	95.23	30.71	11.75	18.13
	Tonga	114.76	25.39	9.33	10.36
	Uganda 1	90.98	30.34	4.51	50.01
	Uganda 2	102.91	24.47	5.63	31.42
Average		90.82		8.06	

Costa Rica: Plant crop; Uganda 1: Plant crop; Uganda 2: Ratoon crop; * :missing data

Table 5. Average and coefficient of variation (Cv) of the disease development time (DDT) in days and youngest leaf spotted (YLS). IMTP Phase II. (Continued)

Genotype	Location	DDT	DDT	YLS	YLS
		Avg	*Cv*	*Avg*	*Cv*
Pisang Ceylan	Cameroon	147.62	30.89	11.32	33.76
	Costa Rica	58.00	35.93	8.55	14.90
	Honduras	84.33	34.47	8.85	29.33
	Philippines	87.20	34.85	11.24	21.87
	Tonga	100.91	14.37	9.85	10.69
	Uganda 1	129.23	23.96	5.92	44.33
	Uganda 2	138.58	19.71	6.64	36.36
Average		101.79		9.29	
Calcutta 4	Cameroon	0.00	0.00	0.00	0.00
	Costa Rica	48.33	34.01	7.90	12.06
	Honduras	*	*	*	*
	Philippines	61.50	12.64	11.50	18.44
	Tonga	0	0	0	0
	Uganda 1	*	*	*	*
	Uganda 2	187.00	*	2.00	*
Average		26.47		4.79	
Pisang Lilin	Cameroon	*	*	*	
	Costa Rica	45.00	52.11	7.85	24.47
	Honduras	63.10	26.46	6.73	30.45
	Philippines	48.02	31.68	8.68	19.99
	Tonga	*	*	*	*
	Uganda 1	57.53	23.76	4.55	26.84
	Uganda 2	69.84	27.59	4.89	38.15
Average		55.99		7.29	
Pisang Berlin	Cameroon	87.91	29.45	9.13	30.43
	Costa Rica	47.00	39.55	8.21	20.23
	Honduras	65.97	31.82	6.87	34.42
	Philippines	81.28	50.78	9.48	16.11
	Tonga	75.82	9.22	7.91	20.02
	Uganda 1	73.65	15.38	5.21	34.41
	Uganda 2	95.52	28.03	7.03	17.02
Average		71.08		7.90	
Niyarma-Yik	Cameroon	48.37	14.91	4.69	26.14
	Costa Rica	20.40	25.62	5.28	11.66
	Honduras	42.50	20.43	4.65	22.10
	Philippines	59.80	18.19	6.57	19.70
	Tonga	44.73	14.63	5.25	17.44
	Uganda 1	61.10	23.76	4.14	33.77
	Uganda 2	85.16	34.25	5.14	27.70
Average		46.93		4.78	
Local cultivar	Cameroon	61.42	17.85	6.32	28.01
	Costa Rica	18.09	17.12	4.86	14.66
	Honduras	64.16	26.54	7.31	29.14
	Philippines	60.25	18.23	7.23	14.20
	Tonga	52.88	13.22	5.05	9.71
	Uganda 1	58.66	19.22	4.26	29.14
	Uganda 2	85.79	33.37	5.55	28.97
Average		52.47		5.71	

Costa Rica: Plant crop; Uganda 1: Plant crop; Uganda 2: Ratoon crop; * :missing data

Table 6. Regression of three important disease traits on the environmental index.

Genotype	Infection Index				Disease development time				Youngest leaf spotted			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Calcutta 4	5.71	0.85	0.031	83.0	31.9	-0.85	0.744	15.3	4.57	3.43	0.211	89.4
FHIA-23	17.4	0.713	0.274	28.6	91.6	1.57	0.104	52.4	8.64	0.868	0.253	30.8
Local cultivar	35.2	1.86	0.028	84.1	55.6	1.14	0.081	69.1	6.07	0.453	0.362	27.7
Niyarma-Yik	33.7	1.20	0.038	69.9	46.4	0.734	0.092	54.9	5.16	0.595	0.015	80.7
Pisang Berlin	29.3	1.69	0.000	96.8	71.3	0.682	0.092	55.0	7.81	0.758	0.113	50.6
Pisang Ceylan	19.0	1.34	0.004	89.7	101.0	1.46	0.157	43.0	9.27	0.794	0.220	34.5
Pisang Lilin	21.9	2.12	0.095	81.9	56.1	0.262	0.417	34.0	6.85	0.970	0.028	94.4
PA 03.22	27.4	0.444	0.334	23.2	70.1	0.606	0.239	32.3	6.29	1.06	0.027	74.6
PV 03.44	26.3	0.464	0.321	24.3	72.1	0.354	0.324	24.0	6.74	1.09	0.029	73.4
Saba	23.3	0.259	0.583	8.1	90.1	1.28	0.009	84.9	8.18	1.41	0.007	86.3
SH 3436-9	21.9	1.43	0.022	76.9	84.9	1.75	0.069	60.4	8.19	0.937	0.134	46.8
Williams	*	*	*	*	*	*	*	*				
Yangambi Km 5	15.1	0.721	0.239	32.3	68.5	0.99	0.462	14.2	6.96	1.11	0.358	21.2

* : regression not possible, too few data available.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt.

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
FHIA-01	Australia	21.19	22.70	589.84	9.16	9.58	9.41	133.16	15.30
	Brazil	13.96	33.20	428.74	11.54	8.11	17.40	114.42	23.91
	Honduras	14.97	26.23	590.69	10.27	8.13	17.30	117.47	15.88
	Indonesia	11.32	20.86	388.87	11.24	8.71	8.67	112.71	10.89
	Malaysia	20.72	25.32	318.87	5.48	9.40	15.47	144.60	21.23
	Phil (Sto Tomas)	20.33	26.19	316.18	8.15	10.00	7.91	156.18	12.22
	Phil (Bago Oshiro)	19.80	53.75	348.17	17.22	9.33	12.98	145.67	10.24
	South Africa	16.20	37.25	714.20	14.21	9.00	14.81	119.40	15.37
	Spain	10.77	60.35	543.18	13.75	10.36	10.81	149.18	16.15
	Taiwan	24.16	26.00	354.82	7.01	9.50	11.44	144.89	10.95
	Uganda	20.32	32.54	596.83	12.40	9.73	11.35	**	**
Average		17.61		471.85		9.26		133.77	
FHIA-03	Australia	15.76	13.19	491.33	6.56	6.67	12.25	103.67	12.69
	Brazil	19.08	31.59	447.65	12.00	7.06	19.12	111.56	28.52
	Honduras	18.52	18.03	535.69	5.67	8.08	16.22	131.58	21.39
	Indonesia	14.32	31.59	380.40	7.59	7.20	6.21	110.40	14.00
	Malaysia	23.11	26.25	353.57	7.76	8.21	11.87	144.64	17.37
	Phil (Sto Tomas)	27.58	29.77	365.62	6.63	10.17	9.67	153.33	29.24
	Phil (Bago Oshiro)	28.30	29.92	316.00	9.32	9.67	15.80	178.67	21.84
	South Africa	13.43	83.75	664.75	6.20	6.75	14.18	82.67	36.14
	Spain	6.50	97.91	512.00	*	6.50	32.64	107.50	49.33
	Taiwan	29.84	21.80	372.89	2.75	8.77	12.45	156.11	12.46
	Uganda	28.33	30.00	569.86	13.32	8.83	18.14	**	**
Average		20.43		455.43		7.99		128.01	
FHIA-17	Australia	24.19	12.65	648.71	6.04	11.33	4.56	183.67	8.50
	Brazil	17.89	20.85	576.06	10.08	9.25	10.06	137.06	14.95
	Honduras	14.07	4.57	650.00	6.31	10.00	14.14	148.50	7.14
	Indonesia	7.77	0.55	440.00	14.78	8.00	*	130.00	30.46
	Malaysia	23.52	16.82	362.33	7.17	9.50	8.81	160.50	4.89
	Phil (Sto Tomas)	27.70	16.63	367.18	7.51	12.13	9.93	194.94	11.39
	Phil (Bago Oshiro)	43.40	*	382.00	*	15.00	*	250.00	*
	South Africa	17.71	43.33	701.62	11.71	11.71	11.78	172.00	26.25
	Spain	18.50	43.58	652.80	12.61	14.75	20.24	240.80	13.84
	Taiwan	43.87	12.29	400.75	1.75	12.14	16.76	205.40	21.59
	Uganda	39.40	27.45	550.91	12.75	12.09	24.10	**	**
Average		25.27		521.12		11.45		182.29	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
FHIA-23	Australia	15.55	40.42	607.33	17.11	10.67	14.32	188.33	7.07
	Brazil	19.96	20.45	617.47	9.21	9.35	10.65	135.59	19.02
	Honduras	**	**	497.00	*	**	**	**	**
	Indonesia	6.90	*	499.00	*	7.67	15.06	99.67	20.30
	Malaysia	20.89	23.19	378.33	10.17	10.58	14.78	164.83	20.40
	Phil (Sto Tomas)	26.10	19.42	415.42	8.37	12.18	19.01	205.45	20.59
	Phil (Bago Oshiro)	27.03	82.26	393.33	7.54	10.33	36.64	216.33	60.91
	South Africa	5.56	66.03	744.13	9.21	7.25	23.02	97.62	40.25
	Spain	17.00	*	636.00	*	17.00	*	287.00	*
	Taiwan	46.83	21.67	418.00	3.83	14.80	7.40	282.25	2.44
	Uganda	37.40	15.08	577.64	5.87	12.50	11.47	**	**
Average		22.32		525.79		11.23		186.34	
PV 03.44	Australia	8.10	25.81	522.16	9.31	6.21	11.49	81.58	19.05
	Brazil	6.73	29.72	437.05	4.98	5.45	9.37	76.10	10.30
	Honduras	4.08	32.33	519.13	6.65	5.00	11.55	63.00	16.95
	Indonesia	3.83	52.69	360.67	6.23	5.25	18.24	67.00	14.57
	Malaysia	11.19	28.45	366.67	21.23	6.60	20.49	97.53	26.07
	Phil (Sto Tomas)	10.27	27.44	338.42	7.91	6.68	16.58	97.95	22.59
	Phil (Bago Oshiro)	7.33	37.46	300.75	5.91	6.75	14.18	92.75	17.24
	South Africa	11.33	37.58	604.33	2.41	7.08	7.27	99.58	14.22
	Spain	8.58	55.90	579.73	10.96	7.00	14.29	103.50	25.15
	Taiwan	11.00	38.57	417.33	13.20	7.27	23.08	118.67	62.64
	Uganda	10.41	27.19	552.06	11.33	6.75	11.48	**	**
Average		8.44		454.39		6.37		89.77	
PA 03.22	Australia	5.18	25.94	510.37	10.15	6.37	15.00	77.11	22.58
	Brazil	5.90	38.20	454.95	9.73	6.05	17.82	75.05	29.78
	Honduras	3.02	57.01	496.69	11.06	5.77	10.39	69.92	21.66
	Indonesia	4.87	41.07	401.00	14.33	5.75	16.65	72.25	19.85
	Malaysia	6.70	18.31	316.08	15.35	6.67	9.77	95.33	10.31
	Phil (Sto Tomas)	7.25	17.92	325.30	7.64	7.50	8.09	112.25	9.81
	Phil (Bago Oshiro)	6.43	46.30	336.00	14.38	6.67	12.25	88.50	15.96
	South Africa	11.60	23.29	596.13	3.78	7.21	19.23	109.93	14.28
	Spain	9.65	24.69	548.15	6.83	8.31	9.04	123.23	9.53
	Taiwan	5.40	31.46	376.80	4.54	7.60	11.77	96.75	9.52
	Uganda	7.08	35.31	579.47	13.72	7.00	18.44	**	**
Average		6.64		449.18		6.81		92.03	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
GCTCV 119	Brazil	4.38	59.07	628.42	14.52	5.00	21.91	73.17	26.91
	Honduras	3.09	62.62	537.60	10.11	5.60	27.08	64.00	43.06
	Indonesia	3.70	49.69	448.50	6.78	4.50	22.22	56.75	8.19
	Malaysia	15.24	32.41	387.36	8.85	7.36	21.73	128.50	18.80
	Phil (Sto Tomas)	11.88	48.60	403.70	9.07	7.20	20.50	124.50	33.07
	Phil (Bago Oshiro)	11.06	47.39	488.00	5.73	6.40	17.82	99.20	26.28
	South Africa	3.33	44.97	811.00	1.91	6.00	25.82	89.83	26.24
	Spain	**	**	**	**	**	**	**	**
	Taiwan	22.17	4.70	431.33	4.28	10.20	21.25	207.33	19.52
	Uganda	15.80	26.25	661.50	3.89	7.80	16.72	**	**
Average		10.07		533.05		6.67		105.41	
GCTCV 215	Australia	17.53	19.68	675.25	1.95	10.12	8.24	167.25	13.57
	Brazil	8.21	31.29	587.76	10.47	6.77	12.29	90.15	18.53
	Honduras	14.63	3.29	654.50	5.29	7.50	28.28	103.50	44.41
	Indonesia	3.65	*	366.00	*	7.00	*	79.00	*
	Malaysia	12.37	21.03	325.56	4.92	8.06	7.93	118.28	12.82
	Phil (Sto Tomas)	9.00	31.66	413.17	10.81	8.08	16.22	110.50	21.40
	Phil (Bago Oshiro)	11.60	*	489.00	*	8.00	*	123.00	*
	South Africa	6.35	38.37	805.29	2.28	8.14	17.98	115.58	53.80
	Spain	10.50	20.20	674.00	7.97	10.50	6.73	175.50	6.85
	Taiwan	20.53	18.94	402.17	1.65	7.56	17.65	117.33	15.54
	Uganda	16.55	38.57	583.54	12.48	8.55	12.12	**	**
Average		11.90		543.29		8.21		120.01	
Burro CEMSA	Brazil	17.57	20.72	455.65	7.72	6.45	19.79	79.55	22.90
	Honduras	11.67	29.69	528.29	10.16	6.59	20.12	86.71	38.91
	Indonesia	5.41	25.10	465.00	8.25	5.25	9.52	58.00	31.70
	Malaysia	16.33	34.11	360.82	11.46	6.82	18.85	91.35	21.59
	Phil (Sto Tomas)	25.69	19.12	356.72	8.76	9.11	12.98	132.44	12.06
	Phil (Bago Oshiro)	13.90	*	326.00	*	10.00	*	143.00	*
	South Africa	10.98	60.52	641.60	3.94	5.70	46.82	60.60	55.87
	Spain	10.03	34.51	580.00	11.74	6.56	13.59	83.56	17.71
	Taiwan	23.90	9.42	386.33	2.99	8.22	15.83	127.50	24.04
	Uganda	13.29	19.78	541.00	10.60	5.29	18.00	**	**
Average		14.88		464.14		7.00		95.86	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Saba	Brazil	17.22	21.61	441.00	10.68	6.10	18.35	75.95	23.38
	Honduras	14.25	29.19	536.43	7.90	6.46	33.80	83.69	41.50
	Indonesia	6.04	7.73	482.25	7.93	5.00	28.28	44.00	16.07
	Malaysia	12.27	25.24	469.80	14.86	6.40	17.82	81.00	19.77
	Phil (Sto Tomas)	27.60	20.05	358.89	7.05	9.44	13.21	142.22	16.86
	Phil (Bago Oshiro)	**	**	**	**	**	**	**	**
	South Africa	16.26	47.85	624.33	3.14	6.83	14.39	83.50	24.09
	Spain	11.05	35.70	578.06	14.60	6.35	14.66	82.06	18.25
	Taiwan	23.50	31.34	375.25	3.44	7.67	8.50	118.67	15.29
	Uganda	12.20	17.77	589.80	15.35	6.20	38.51	**	**
Average		15.75		541.86		6.76		94.74	
Pisang Nangka	Australia	5.12	21.14	544.33	9.76	5.00	7.84	46.86	11.95
	Brazil	14.71	28.59	530.47	8.88	5.81	9.36	77.75	12.14
	Honduras	10.66	48.89	585.75	13.45	8.00	27.00	115.75	36.10
	Indonesia	6.77	48.81	407.00	11.03	4.33	13.32	52.67	23.74
	Malaysia	17.13	25.38	350.10	5.50	6.00	15.71	84.50	19.14
	Phil (Sto Tomas)	21.23	16.55	384.69	7.99	7.00	13.04	104.00	17.42
	South Africa	9.98	56.48	748.94	8.81	6.87	21.16	90.44	24.47
	Spain	7.89	36.75	640.14	16.72	7.17	13.72	94.33	27.03
	Taiwan	26.20	28.36	392.40	3.34	6.50	16.45	101.80	18.94
	Uganda	14.30	30.58	557.82	9.91	6.60	16.29	**	**
Average		13.40		514.16		6.33		85.34	
Cultivar Rose	Australia	2.77	25.71	480.58	7.11	8.74	9.98	95.84	22.17
	Brazil	4.11	49.03	439.47	11.62	7.94	19.53	89.94	32.81
	Honduras	2.65	65.48	590.38	12.45	9.00	23.57	127.08	38.53
	Indonesia	2.04	26.52	325.25	7.58	7.67	10.65	94.25	13.46
	Malaysia	3.78	30.53	277.47	11.60	8.79	12.90	114.63	17.24
	Phil (Sto Tomas)	12.77	26.72	455.33	11.50	10.00	14.14	170.11	15.42
	South Africa	5.58	141.40	595.37	13.59	8.29	18.47	113.80	29.67
	Spain	3.35	66.91	576.08	11.77	7.33	24.21	106.73	37.92
	Taiwan	3.19	59.83	272.90	16.21	9.15	8.75	133.60	9.15
	Uganda	5.82	55.86	566.33	13.71	8.09	21.01	**	**
Average		4.61		457.92		8.50		116.22	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Pisang Jari Buaya	Australia	11.86	39.03	620.24	9.99	9.93	16.35	159.53	19.78
	Brazil	11.30	38.26	561.56	9.27	7.56	15.87	126.22	21.78
	Honduras	10.17	16.80	664.83	1.80	7.67	13.47	129.00	11.44
	Indonesia	3.43	58.90	413.00	12.46	6.33	32.87	101.00	46.34
	Malaysia	16.00	10.04	328.18	1.95	8.36	9.67	134.45	8.51
	Phil (Sto Tomas)	4.72	23.86	279.21	13.36	9.53	6.42	136.63	11.15
	Phil (Bago Oshiro)	3.31	68.28	325.43	15.16	8.00	16.14	98.57	26.77
	South Africa	6.99	45.37	765.71	8.46	7.86	41.72	120.55	49.47
	Spain	**	*	636.00	*	**	**	**	**
	Taiwan	20.17	23.99	423.11	9.84	9.89	22.30	170.00	29.24
	Uganda	5.72	48.48	611.45	6.39	7.78	33.27	**	**
Average		9.37		511.70		8.29		130.66	
Pisang Lilin	Brazil	1.72	69.37	420.67	23.22	3.87	27.42	44.07	38.63
	Honduras	0.57	36.25	521.00	8.34	3.38	22.05	39.87	31.51
	Indonesia	0.24	*	340.00	*	3.00	*	27.00	10.48
	Malaysia	4.42	179.36	380.17	3.76	5.00	40.00	72.83	94.72
	Phil (Sto Tomas)	1.34	46.68	294.50	14.69	3.88	25.57	40.18	31.96
	Phil (Bago Oshiro)	**	**	**	**	**	**	**	**
	South Africa	**	**	**	**	**	**	**	**
	Spain	**	**	**	**	**	**	**	**
	Taiwan	**	**	**	**	5.67	44.41	**	**
	Uganda	9.00	*	509.00	*	4.00	*	**	**
Average		2.88		410.89		4.11		44.79	
Bluggoe	Australia	5.98	37.69	447.50	3.31	3.33	24.49	33.50	30.31
	Brazil	14.25	38.11	484.05	14.59	5.41	18.55	63.00	22.02
	Honduras	9.66	25.27	548.69	7.87	5.00	14.77	56.42	17.73
	Indonesia	6.32	*	427.00	*	4.00	35.36	39.50	30.43
	Malaysia	9.42	44.47	343.00	5.02	4.83	20.34	55.17	25.10
	Phil (Sto Tomas)	22.69	16.74	369.75	11.00	7.25	12.56	92.30	13.46
	Phil (Bago Oshiro)	**	**	**	**	**	**	**	**
	South Africa	4.20	67.27	752.62	10.09	5.62	58.53	73.62	81.02
	Spain	6.05	55.98	662.10	10.20	4.80	29.13	49.80	38.60
	Taiwan	**	**	**	**	6.25	24.00	100.00	*
	Uganda	14.93	22.82	545.87	10.81	5.86	21.02	**	**
Average		10.39		508.95		5.24		62.59	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Williams	Australia	16.37	51.86	579.00	*	9.67	23.89	177.67	35.21
	Brazil	4.67	96.74	583.25	13.54	4.14	62.99	53.14	84.32
	Honduras	7.65	47.34	620.00	9.55	7.50	21.91	92.67	36.31
	Indonesia	5.01	46.95	403.00	8.42	6.00	23.57	75.50	17.79
	Malaysia	5.59	111.20	321.87	11.48	5.50	45.58	78.87	67.11
	Phil (Sto Tomas)	8.94	77.84	374.44	16.17	6.67	43.08	104.33	54.77
	South Africa	7.39	49.67	778.40	7.93	7.60	31.69	120.80	36.44
	Spain	**	**	**	**	**	**	**	**
	Taiwan	24.00	*	393.00	**	6.00	23.57	139.00	*
	Uganda	3.50	20.20	607.33	9.29	5.50	12.86	**	**
Average		9.24		517.81		6.51		105.25	
Pisang Ceylan	Australia	17.81	50.55	531.96	7.33	10.37	31.55	151.96	43.21
	Brazil	18.29	24.35	475.47	6.89	9.95	14.79	152.89	17.11
	Honduras	14.69	23.13	553.14	8.73	11.36	16.42	182.86	24.71
	Indonesia	6.69	33.19	411.00	7.04	10.14	13.26	141.71	23.65
	Malaysia	17.43	22.72	310.47	4.49	9.88	7.91	164.35	9.47
	Phil (Sto Tomas)	18.45	22.16	321.00	16.61	11.95	8.12	211.95	9.58
	Phil (Bago Oshiro)	21.52	38.51	321.67	3.30	12.67	8.15	219.67	9.71
	South Africa	13.44	51.64	739.00	8.38	11.31	17.30	148.37	16.17
	Spain	10.50	49.21	621.14	9.16	12.67	21.57	207.83	22.51
	Taiwan	25.77	20.42	372.00	6.68	10.90	15.26	201.60	13.91
	Uganda	16.64	30.33	529.07	8.20	10.50	19.32	**	**
Average		16.48		471.45		11.06		178.32	
Local cultivar	Brazil	8.36	29.76	479.67	14.09	7.00	12.37	88.00	20.47
	Honduras	14.04	16.89	608.25	5.21	9.30	10.20	138.90	14.72
	Indonesia	5.52	69.69	351.00	6.04	7.00	20.20	100.00	*
	Malaysia	10.70	*	333.00	*	6.00	*	94.00	*
	Phil (Sto Tomas)	16.33	22.05	370.79	13.72	8.68	8.63	136.21	14.93
	Phil (Bago Oshiro)	**	**	**	**	**	**	**	**
	South Africa	15.27	21.45	711.92	9.30	9.00	17.21	121.55	39.22
	Spain	11.33	34.25	513.75	0.96	10.20	8.20	180.60	13.98
	Taiwan	26.75	28.12	408.18	8.05	10.44	22.51	190.00	29.10
	Uganda	16.69	44.58	568.00	11.61	7.50	10.08	**	**
Average		13.89		482.73		8.35		131.16	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Pisang Mas	Australia	5.54	25.48	536.63	8.65	7.00	8.25	122.14	6.79
	Brazil	3.75	48.12	481.79	21.84	4.37	18.43	71.00	24.90
	Honduras	5.95	40.50	624.75	2.89	6.00	23.57	114.00	37.80
	Indonesia	3.13	44.96	289.33	7.98	5.67	20.38	94.50	26.19
	Malaysia	8.45	32.41	269.80	4.22	6.20	13.49	103.00	30.68
	Phil (Sto Tomas)	4.61	38.09	309.00	21.91	6.38	19.75	106.08	24.28
	Phil (Bago Oshiro)	9.20	*	438.00	*	7.00	*	139.00	*
	South Africa	1.89	85.19	666.11	13.04	5.43	33.39	59.86	63.32
	Spain	17.50	*	585.00	17.65	13.00	*	234.00	*
	Taiwan	**	**	**	**	9.00	*	**	**
	Uganda	4.00	37.50	601.33	10.47	6.44	15.73	**	**
Average		6.40		480.17		6.95		115.95	
Yangambi Km 5	Australia	11.23	6.91	667.33	1.47	8.67	13.32	170.00	20.45
	Brazil	12.51	38.17	523.65	10.81	6.50	21.47	113.15	34.07
	Honduras	9.34	19.02	653.91	4.23	8.18	14.27	151.27	21.86
	Indonesia	**	**	**	**	**	**	**	**
	Malaysia	17.36	12.84	362.80	6.76	8.10	9.11	178.56	10.53
	Phil (Sto Tomas)	15.67	36.48	405.68	14.21	9.26	19.33	186.53	22.36
	Phil (Bago Oshiro)	18.67	6.21	357.67	15.34	9.00	11.11	180.67	12.78
	South Africa	5.53	85.58	782.60	4.74	7.60	30.29	106.20	49.12
	Spain	**	**	**	**	**	**	**	**
	Taiwan	27.05	17.40	379.50	5.69	8.83	4.62	187.00	9.94
	Uganda	14.36	34.71	561.17	8.86	8.64	15.77	**	**
Average		14.64		521.59		8.31		159.17	
Calcutta	Australia	0.91	34.84	448.21	0.83	6.37	14.05	92.32	20.93
	Brazil	0.92	55.82	405.50	7.58	6.13	13.59	87.80	22.12
	Honduras	0.52	55.24	524.17	9.56	6.14	21.90	93.86	46.05
	Indonesia	1.06	72.04	307.67	17.83	6.33	9.12	83.33	12.49
	Malaysia	1.68	45.88	295.68	14.33	6.26	16.70	89.26	27.54
	Phil (Sto Tomas)	17.75	50.59	348.80	14.32	10.33	24.35	144.00	33.19
	South Africa	1.29	82.05	552.22	4.80	6.67	10.61	106.83	14.93
	Spain	**	**	512.00	*	**	**	**	**
	Taiwan	1.62	56.81	399.80	20.97	7.70	28.09	169.00	31.52
	Uganda	1.95	146.77	539.21	9.96	7.00	13.47	**	**
Average		3.08		433.33		6.99		108.30	

*: only one data point; no Cv possible; **: missing data.

Table 7. Average and coefficient of variation (Cv) on the main agronomic traits classified by genotype and site, IMTP II Fusarium wilt. (Continued)

Genotype	Location	Bunch weight		Days to harvest		Number of hands		Fruit number	
		kg	Cv	days	Cv	#	Cv	#	Cv
Gros Michel	Australia	10.80	*	620.00	*	8.00	*	109.00	*
	Brazil	10.11	16.26	632.58	15.69	5.00	28.28	53.50	52.08
	Honduras	9.30	31.02	632.50	5.70	8.00	*	120.00	1.18
	Indonesia	9.50	*	387.50	18.80	10.00	*	173.00	*
	Phil (Sto Tomas)	19.98	28.90	350.21	10.14	8.16	12.44	121.84	12.14
	Phil (Bago Oshiro)	19.30	*	326.00	*	10.00	*	148.00	*
	South Africa	8.11	37.57	715.33	12.43	7.00	14.29	86.33	12.17
	Spain	**	**	**	**	**	**	**	**
	Taiwan	**	**	**	**	**	**	**	**
	Uganda	19.56	18.50	537.11	6.37	8.75	13.31	**	**
Average		13.33		525.15		8.11		115.95	

*: only one data point; no Cv possible; **: missing data.

Table 8. Regression of four important agronomic traits on the environmental index for the Fusarium wilt trial.

Genotype	Bunch weight (kg)				Days to harvest			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Bluggoe	12.3	1.37	0.022	55.1	487	1.02	0.001	83.9
Burro CEMSA	14.6	0.996	0.007	61.9	472	0.816	0.000	91.3
Calcutta 4	3.1	0.367	0.389	10.7	426	0.738	0.000	85.0
Cv Rose	4.66	0.226	0.335	11.6	449	0.924	0.001	75.6
FHIA-01	17.5	0.762	0.002	65.8	474	1.12	0.000	95.1
FHIA-03	20.2	1.29	0.003	63.4	457	0.872	0.000	94.0
FHIA-17	24.8	2.39	0.000	84.8	523	1.06	0.000	93.1
FHIA-23	21.0	2.44	0.000	83.4	528	0.90	0.000	83.2
GCTCV 119	9.41	1.18	0.002	77.7	556	1.05	0.000	86.8
GCTCV 215	11.8	0.710	0.029	42.8	546	1.22	0.000	91.0
Gros Michel	14.3	1.19	0.002	81.9	508	1.16	0.001	87.0
Local cultivar	14.1	1.07	0.002	75.3	480	0.994	0.000	92.9
Pisang Ceylan	16.3	0.982	0.000	79.8	474	1.13	0.000	96.7
Pisang Jari Buaya	9.19	0.458	0.255	15.8	515	1.33	0.000	96.0
Pisang Lilin	3.37	0.486	0.236	32.7	435	0.793	0.010	83.9
Pisang Mas	6.58	0.223	0.625	3.1	472	1.12	0.000	87.3
Pisang Nangka	13.7	1.23	0.001	74.8	504	1.05	0.000	97.3
PA 03.22	6.65	-0.025	0.884	0.2	451	0.829	0.000	93.2
PV 03.44	8.38	0.334	0.065	32.9	456	0.831	0.000	90.4
Saba	15.8	0.955	0.028	52.0	493	0.693	0.003	72.9
Williams	9.3	0.889	0.056	42.9	519	1.21	0.000	98.1
Yangambi Km 5	13.0	1.33	0.000	88.3	526	1.20	0.000	94.7

Table 8. Regression of four important agronomic traits on the environmental index for the Fusarium wilt trial. (Continued)

Clone	Number of hands				Average weight of fruits (g)			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Bluggoe	5.25	0.356	0.374	10.0	169	2.47	0.026	66.4
Burro CEMSA	6.93	0.973	0.040	42.9	152	1.16	0.054	48.9
Calcutta 4	7.29	1.13	0.034	49.6	21.7	0.186	0.768	1.9
Cv Rose	8.51	0.182	0.526	5.2	33.5	0.111	0.660	3.4
FHIA-01	9.21	0.548	0.004	62.0	118	0.891	0.022	55.4
FHIA-03	7.95	0.428	0.292	12.2	131	1.45	0.007	66.5
FHIA-17	11.3	1.98	0.000	87.2	118	1.83	0.000	92.3
FHIA-23	10.9	2.09	0.016	53.9	96.8	1.50	0.000	88.8
GCTCV 119	6.79	1.17	0.049	44.7	71.0	0.784	0.098	45.2
GCTCV 215	8.14	0.701	0.042	38.5	81.7	1.41	0.001	80.7
Gros Michel	8.20	0.650	0.337	15.4	129	2.8	0.004	89.4
Local cultivar	8.42	1.08	0.025	53.6	91.4	0.873	0.018	70.4
Pisang Ceylan	11.0	0.792	0.003	64.2	87.8	1.02	0.004	71.9
Pisang Jari Buaya	8.35	0.864	0.024	48.9	59.0	0.983	0.085	41.4
Pisang Lilin	4.28	0.588	0.153	36.2	24.1	0.512	0.030	94.1
Pisang Mas	6.80	1.70	0.007	57.8	48.2	0.319	0.479	8.7
Pisang Nangka	6.35	0.489	0.192	20.2	148	2.16	0.001	86.8
PA 03.22	6.75	0.617	0.004	61.7	66.1	- 0.225	0.306	14.8
PV 03.44	6.32	0.555	0.011	53.1	91.0	0.699	0.024	54.0
Saba	6.77	0.709	0.088	35.9	165	0.835	0.104	44.1
Williams	6.67	0.725	0.311	14.6	73.9	1.25	0.044	59.0
Yangambi Km 5	8.24	0.869	0.002	77.4	74.8	1.44	0.001	92.3

Table 8. Regression of internal symptoms rate on the environmental index for the Fusarium wilt trial.

Clone	Internal symptoms			
	Constant	Slope (ß)	*P* (ß ≠ 0)	R^2 (%)
Bluggoe	0.740	1.03	0.002	70.4
Burro CEMSA	0.625	1.22	0.001	79.2
Calcutta 4	0.930	0.023	0.934	0.1
Cv Rose	0.916	-0.003	0.991	0.00
FHIA-01	0.674	0.633	0.111	25.8
FHIA-03	0.533	0.995	0.005	59.5
FHIA-17	0.598	1.07	0.001	72.0
FHIA-23	0.617	1.16	0.002	72.8
GCTCV 119	0.870	0.657	0.022	55.3
GCTCV 215	0.777	1.08	0.000	79.1
Gros Michel	0.467	0.933	0.019	51.7
Local cultivar	0.589	1.14	0.001	76.1
Pisang Ceylan	0.641	1.03	0.001	69.6
Pisang Jari Buaya	0.850	0.696	0.038	39.5
Pisang Lilin	0.777	0.971	0.019	56.5
Pisang Mas	0.580	1.19	0.002	66.2
Pisang Nangka	0.732	0.846	0.049	40.2
PA 03.22	0.625	1.08	0.000	76.3
PV 03.44	0.673	1.22	0.000	82.0
Saba	0.622	1.21	0.000	88.2
Williams	0.694	1.35	0.000	84.9
Yangambi Km 5	0.555	1.16	0.004	66.6

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites.

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
FHIA-01	Australia	1.0	-	1.0	1.0	21.0
	Brazil	1.5	0.8	1.0	3.0	19.0
	Honduras	1.0	-	1.0	1.0	17.0
	Indonesia	2.1	1.5	1.0	4.0	7.0
	Malaysia	1.0	-	1.0	1.0	15.0
	Phil (Sto Tomas)	2.0	-	2.0	2.0	17.0
	Phil (Bago Oshiro)	4.1	2.3	1.0	6.0	7.0
	South Africa	2.0	2.0	1.0	6.0	20.0
	Spain	4.2	1.7	1.0	6.0	18.0
	Taiwan	1.0	-	1.0	1.0	12.0
	Uganda	1.3	0.7	1.0	3.0	12.0
Average		1.9		1.1	3.1	15.0
FHIA-03	Australia	5.8	0.9	2.0	6.0	21.0
	Brazil	2.7	1.5	1.0	5.0	20.0
	Honduras	1.0	-	1.0	1.0	18.0
	Indonesia	1.3	0.5	1.0	2.0	4.0
	Malaysia	1.0	-	1.0	1.0	14.0
	Phil (Sto Tomas)	2.1	0.3	2.0	3.0	10.0
	Phil (Bago Oshiro)	5.6	0.6	5.0	6.0	5.0
	South Africa	3.5	2.4	1.0	6.0	20.0
	Spain	4.3	1.7	1.0	6.0	13.0
	Taiwan	1.7	1.6	1.0	6.0	13.0
	Uganda	1.4	1.1	1.0	4.0	7.0
Average		2.7		1.5	4.2	13.2
FHIA-17	Australia	2.1	1.9	1.0	6.0	19.0
	Australia	*	*	*	*	*
	Brazil	1.0	-	1.0	1.0	18.0
	Honduras	1.0	-	1.0	1.0	16.0
	Indonesia	2.0	-	2.0	2.0	2.0
	Malaysia	1.0	-	1.0	1.0	6.0
	Phil (Sto Tomas)	2.0	0.4	1.0	3.0	17.0
	Phil (Bago Oshiro)	5.8	0.4	5.0	6.0	9.0
	South Africa	2.3	2.0	1.0	6.0	19.0
	Spain	2.4	2.0	1.0	6.0	19.0
	Taiwan	4.3	2.2	1.0	6.0	9.0
	Uganda	1.3	0.9	1.0	4.0	11.0
Average		2.3		1.5	3.6	12.6

*: missing data; N= number of replications evaluated

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
FHIA-23	Australia	4.3	2.3	1.0	6.0	21.0
	Brazil	1.2	0.5	1.0	3.0	17.0
	Honduras	1.0	-	1.0	1.0	10.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	12.0
	Phil (Sto Tomas)	1.7	0.5	1.0	2.0	14.0
	Phil (Bago Oshiro)	4.1	2.4	-	6.0	8.0
	South Africa	2.5	2.4	1.0	6.0	20.0
	Spain	5.0	1.5	1.0	6.0	16.0
	Taiwan	2.3	1.6	1.0	5.0	8.0
	Uganda	1.0	-	1.0	1.0	11.0
Average		2.4		0.9	3.7	12.5
PV 03.44	Australia	2.4	1.7	1.0	6.0	20.0
	Brazil	1.0	-	1.0	1.0	20.0
	Honduras	1.0	-	1.0	1.0	17.0
	Indonesia	1.7	0.6	1.0	2.0	3.0
	Malaysia	1.0	-	1.0	1.0	15.0
	Phil (Sto Tomas)	2.0	-	2.0	2.0	19.0
	Phil (Bago Oshiro)	4.9	1.7	2.0	6.0	7.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	3.2	1.5	1.0	6.0	17.0
	Taiwan	2.8	1.9	1.0	6.0	11.0
	Uganda	1.1	0.2	1.0	2.0	17.0
Average		2.0		1.2	3.1	15.1
PA 03.22	Australia	2.2	1.8	1.0	6.0	20.0
	Brazil	1.2	0.5	1.0	3.0	20.0
	Honduras	1.1	0.3	1.0	2.0	15.0
	Indonesia	2.0	1.0	1.0	3.0	3.0
	Malaysia	1.0	-	1.0	1.0	12.0
	Phil (Sto Tomas)	2.0	-	2.0	2.0	20.0
	Phil (Bago Oshiro)	5.0	1.4	2.0	6.0	7.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	2.4	1.8	1.0	6.0	16.0
	Taiwan	4.3	2.2	1.0	6.0	14.0
	Uganda	1.4	1.3	1.0	6.0	15.0
Average		2.1		1.2	3.8	14.7

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
GCTCV 119	Australia	1.1	0.2	1.0	2.0	20.0
	Brazil	1.0	-	1.0	1.0	8.0
	Honduras	1.0	-	1.0	1.0	10.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	14.0
	Phil (Sto Tomas)	1.2	0.4	1.0	2.0	12.0
	Phil (Bago Oshiro)	2.0	1.6	1.0	5.0	6.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	1.0	-	1.0	1.0	5.0
	Taiwan	2.3	2.2	1.0	6.0	7.0
	Uganda	1.0	-	1.0	1.0	6.0
Average		1.3		1.0	2.1	9.8
GCTCV 215	Australia	1.6	1.4	1.0	6.0	21.0
	Brazil	1.0	-	1.0	1.0	15.0
	Honduras	1.0	-	1.0	1.0	8.0
	Indonesia	1.0	*	1.0	1.0	1.0
	Malaysia	1.0	-	1.0	1.0	18.0
	Phil (Sto Tomas)	1.9	0.4	1.0	2.0	13.0
	Phil (Bago Oshiro)	5.6	1.1	3.0	6.0	8.0
	South Africa	1.1	0.5	1.0	3.0	20.0
	Spain	2.6	2.1	1.0	6.0	12.0
	Taiwan	1.2	0.6	1.0	3.0	10.0
	Uganda	1.0	-	1.0	1.0	13.0
Average		1.7		1.2	2.8	12.6
Burro CEMSA	Brazil	2.0	1.6	1.0	6.0	20.0
	Honduras	1.1	0.5	1.0	3.0	18.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	17.0
	Phil (Sto Tomas)	1.9	0.2	1.0	2.0	18.0
	Phil (Bago Oshiro)	5.3	0.7	4.0	6.0	9.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	4.1	1.1	2.0	6.0	19.0
	Taiwan	4.9	1.3	3.0	6.0	11.0
	Uganda	1.0	-	1.0	1.0	7.0
Average		2.4		1.6	3.5	13.8

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
Saba	Brazil	1.2	0.8	1.0	4.0	16.0
	Honduras	1.2	0.7	1.0	4.0	18.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	5.0
	Phil (Sto Tomas)	2.0	-	2.0	2.0	19.0
	Phil (Bago Oshiro)	6.0	-	6.0	6.0	2.0
	South Africa	1.4	1.1	1.0	5.0	20.0
	Spain	4.0	1.2	2.0	6.0	20.0
	Taiwan	4.9	1.5	2.0	6.0	13.0
	Uganda	1.0	-	1.0	1.0	5.0
Average		2.5		1.9	3.8	12.0
Pisang Nangka	Australia	1.0	-	1.0	1.0	19.0
	Brazil	1.5	1.0	1.0	4.0	16.0
	Honduras	1.0	-	1.0	1.0	12.0
	Indonesia	1.0	-	1.0	1.0	2.0
	Malaysia	1.0	-	1.0	1.0	10.0
	Phil (Sto Tomas)	1.5	0.5	1.0	2.0	13.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	2.1	1.4	1.0	6.0	14.0
	Taiwan	3.5	2.3	1.0	6.0	14.0
	Uganda	1.7	1.2	1.0	4.0	11.0
Average		1.6		1.1	2.8	13.0
Cultivar Rose	Australia	1.0	-	1.0	1.0	21.0
	Brazil	1.1	0.2	1.0	2.0	19.0
	Honduras	1.0	-	1.0	1.0	18.0
	Indonesia	1.5	0.6	1.0	2.0	4.0
	Malaysia	1.0	-	1.0	1.0	19.0
	Phil (Sto Tomas)	1.4	0.5	1.0	2.0	9.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	1.0	-	1.0	1.0	18.0
	Taiwan	1.0	-	1.0	1.0	12.0
	Uganda	1.2	0.4	1.0	2.0	12.0
Average		1.2		1.0	1.5	15.0

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
Pisang Jari Buaya	Australia	1.0	-	1.0	1.0	21.0
	Brazil	1.4	0.9	1.0	3.0	18.0
	Honduras	1.0	-	1.0	1.0	12.0
	Indonesia	1.0	-	1.0	1.0	3.0
	Malaysia	1.0	-	1.0	1.0	11.0
	Phil (Sto Tomas)	2.0	0.7	1.0	3.0	19.0
	Phil (Bago Oshiro)	4.9	1.6	2.0	6.0	8.0
	South Africa	1.0	-	1.0	1.0	21.0
	Spain	1.0	-	1.0	1.0	6.0
	Taiwan	1.1	0.3	1.0	2.0	9.0
	Uganda	1.0	-	1.0	1.0	11.0
Average		1.5		1.1	1.9	12.6
Pisang Lilin	Australia	1.3	1.1	1.0	6.0	21.0
	Brazil	1.0	-	1.0	1.0	18.0
	Honduras	1.0	-	1.0	1.0	15.0
	Indonesia	1.0	-	1.0	1.0	2.0
	Malaysia	1.0	-	1.0	1.0	6.0
	Phil (Sto Tomas)	2.9	1.4	1.0	6.0	19.0
	Phil (Bago Oshiro)	6.0	*	6.0	6.0	1.0
	South Africa	1.3	0.8	1.0	4.0	19.0
	Spain	1.0	-	1.0	1.0	6.0
	Taiwan	*	*	*	*	-
	Uganda	1.0	*	1.0	1.0	1.0
Average		1.8		1.5	2.8	9.8
Bluggoe	Australia	5.5	1.2	2.0	6.0	21.0
	Brazil	3.3	2.0	1.0	6.0	17.0
	Honduras	1.4	1.2	1.0	6.0	18.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	6.0
	Phil (Sto Tomas)	2.0	-	2.0	2.0	20.0
	Phil (Bago Oshiro)	6.0	-	6.0	6.0	4.0
	South Africa	2.4	2.2	1.0	6.0	20.0
	Spain	4.8	0.9	3.0	6.0	17.0
	Taiwan	5.9	0.5	4.0	6.0	14.0
	Uganda	1.2	0.4	1.0	2.0	16.0
Average		3.3		2.2	4.7	13.9

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
Williams	Australia	2.2	2.0	1.0	6.0	21.0
Williams2	Australia	2.4	1.6	1.0	6.0	20.0
	Brazil	1.0	-	1.0	1.0	12.0
	Honduras	1.0	-	1.0	1.0	14.0
	Indonesia	1.0	*	1.0	1.0	1.0
	Malaysia	1.0	-	1.0	1.0	8.0
	Phil (Sto Tomas)	1.6	0.5	1.0	2.0	9.0
	South Africa	1.4	1.2	1.0	6.0	19.0
	Spain	3.0	2.1	1.0	6.0	20.0
	Taiwan	3.2	2.3	1.0	6.0	5.0
	Uganda	1.0	-	1.0	1.0	6.0
Average		1.7		1.0	3.4	12.3
Pisang Ceylan	Australia	1.8	1.5	1.0	6.0	21.0
	Brazil	2.1	1.5	1.0	6.0	19.0
	Honduras	1.1	0.2	1.0	2.0	17.0
	Indonesia	1.0	-	1.0	1.0	4.0
	Malaysia	1.0	-	1.0	1.0	17.0
	Phil (Sto Tomas)	1.8	0.4	1.0	2.0	19.0
	Phil (Bago Oshiro)	3.9	1.8	2.0	6.0	8.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	3.1	1.6	1.0	6.0	18.0
	Taiwan	3.4	2.1	1.0	6.0	13.0
	Uganda	1.7	1.5	1.0	6.0	14.0
Average		2.0		1.1	3.9	15.5
Local cultivar	Brazil	2.8	1.5	1.0	5.0	18.0
	Honduras	1.0	-	1.0	1.0	15.0
	Indonesia	1.0	*	1.0	1.0	1.0
	Malaysia	1.0	*	1.0	1.0	1.0
	Phil (Sto Tomas)	2.1	0.5	2.0	4.0	19.0
	Phil (Bago Oshiro)	5.7	0.5	5.0	6.0	10.0
	South Africa	1.5	1.0	1.0	4.0	20.0
	Spain	5.2	1.7	1.0	6.0	20.0
	Taiwan	2.3	1.8	1.0	6.0	13.0
	Uganda	1.3	1.0	1.0	4.0	10.0
Average		2.3		1.5	3.8	13.0

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
Pisang Mas	Australia	5.2	1.6	1.0	6.0	21.0
	Brazil	1.2	0.8	1.0	4.0	16.0
	Honduras	1.0	-	1.0	1.0	11.0
	Indonesia	3.0	-	3.0	3.0	2.0
	Malaysia	1.0	-	1.0	1.0	5.0
	Phil (Sto Tomas)	2.1	0.6	1.0	4.0	14.0
	Phil (Bago Oshiro)	4.0	2.8	2.0	6.0	2.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	4.0	2.3	1.0	6.0	7.0
	Taiwan	5.7	0.7	4.0	6.0	11.0
	Uganda	1.3	0.9	1.0	4.0	12.0
Average		2.7		1.5	3.8	11.0
Yangambi Km 5	Australia	5.5	1.5	1.0	6.0	21.0
	Brazil	1.1	0.2	1.0	2.0	19.0
	Honduras	1.0	-	1.0	1.0	13.0
	Indonesia	*	*	*	*	-
	Malaysia	1.0	-	1.0	1.0	10.0
	Phil (Sto Tomas)	1.7	0.6	1.0	3.0	19.0
	Phil (Bago Oshiro)	4.3	2.4	1.0	6.0	7.0
	South Africa	3.5	2.4	1.0	6.0	20.0
	Spain	5.0	1.3	2.0	6.0	10.0
	Taiwan	4.8	1.9	1.0	6.0	13.0
	Uganda	1.4	0.9	1.0	4.0	12.0
Average		2.9		1.1	4.1	13.1
Calcutta	Australia	1.0	-	1.0	1.0	21.0
	Brazil	1.0	-	1.0	1.0	18.0
	Honduras	1.4	0.6	1.0	3.0	17.0
	Indonesia	1.0	-	1.0	1.0	2.0
	Malaysia	1.0	-	1.0	1.0	19.0
	Phil (Sto Tomas)	1.8	0.5	1.0	2.0	8.0
	South Africa	1.0	-	1.0	1.0	20.0
	Spain	1.0	-	1.0	1.0	8.0
	Taiwan	1.0	-	1.0	1.0	10.0
	Uganda	1.0	-	1.0	1.0	14.0
Average		1.3		1.0	1.6	13.6

Table 9. Average and standard deviation (St dv) of the internal corm symptoms classified by genotype and location, IMTP Fusarium wilt sites. (Continued)

Genotype	Location	Internal symptoms score				
		Average	St dv	Min	Max	N
Gros Michel	Australia	5.4	1.6	1.0	6.0	20.0
	Brazil	2.4	2.0	1.0	5.0	5.0
	Honduras	1.2	0.6	1.0	3.0	10.0
	Indonesia	1.0	*	1.0	1.0	1.0
	Phil (Sto Tomas)	2.0	0.4	1.0	3.0	19.0
	Phil (Bago Oshiro)	6.0	-	6.0	6.0	5.0
	South Africa	1.9	1.8	1.0	6.0	20.0
	Spain	5.2	0.6	4.0	6.0	14.0
	Taiwan	5.9	0.5	4.0	6.0	14.0
	Uganda	3.2	2.2	1.0	6.0	9.0
Average		3.2		2.0	4.5	11.9

Table 10. Diversity of *Fusarium oxysporum* f.sp. *cubense* in IMTP Phase II locations.

Location	Volatile production	*Musa* genotype
Cudgen, Australia		
VCG 0124	inodoratum	Bluggoe (ABB)
	inodoratum	Calcutta 4 (AAw)
	inodoratum	FHIA-02 (AAAB)
	inodoratum	Gros Michel (AAA)
	inodoratum	Ney Poovan (AB)
	inodoratum	Pisang Ceylan (AAB)
Wamuran, Australia		
VCG 0120	odoratum	Bluggoe
	odoratum	FHIA-03 (AABB)
	odoratum	FHIA-23 (AAAA)
	odoratum	Gros Michel
	odoratum	Igisahira
	odoratum	Pisang Mas (AA)
Cruz das Almas, Brazil		
VCG 0124	inodoratum	Bluggoe
VCG 0125	inodoratum	Bluggoe
Podavur, Tamil Nadu, India		
VCG 0124/5	inodoratum	Pisang Awak (ABB)
VCG 0125	inodoratum	Pisang Awak
	inodoratum	Silk/Rasthali (AAB)
VCG 01213/16	odoratum	Silk/Rasthali
Solok, Indonesia		
VCG 01213/16	odoratum	Bluggoe
	odoratum	FHIA-23
	odoratum	GCTCV 215
	odoratum	Pisang Ceylan
	odoratum	Pisang Mas
	odoratum	Pisang Nangka (AAB)
	odoratum	PV 03-44 (AAAB)
	odoratum	Williams (AAA)
	odoratum	Yangambi Km 5 (AAA)
VCG 01219	odoratum	Kepok
Selangor, Malaysia		
VCG 01213/16	odoratum	Bluggoe
	odoratum	Burro CEMSA (ABB)
	odoratum	FHIA-17 (AAAA)
	odoratum	FHIA-23
	odoratum	Pisang Berangan (AA)
	odoratum	Pisang Ceylan
	odoratum	Pisang Mas
	odoratum	PV 03-44
	odoratum	Williams
VCG 01216	odoratum	Yangambi Km 5
Johor, Malaysia		
VCG 01213/16	odoratum	FHIA-17
	odoratum	Pisang Mas
	odoratum	Pisang Awak
VCG 01213	odoratum	Burro CEMSA
Bago Oshiro, Davao City, Philippines		
VCG 0123	inodoratum	Latundan (AAB)

Table 10. Diversity of *Fusarium oxysporum* f.sp. *cubense* in IMTP Phase II locations. (Continued)

Location	Volatile production	***Musa*** **genotype**
Davao del Norte, Mindanao, Philippines		
VCG 0122	odoratum	Cavendish (AAA)
	odoratum	Pisang Lilin (AA)*
Hazyview, Eastern Transvaal, South Africa		
VCG 0120	odoratum	Bluggoe
	odoratum	Burro CEMSA
	odoratum	Chinese Cavendish (AAA)
	odoratum	FHIA-03
	odoratum	GCTCV 215 (AAA)
VCG 0120/15	odoratum	Bluggoe
	odoratum	Chinese Cavendish
	odoratum	FHIA-03
	odoratum	FHIA-17
	odoratum	FHIA-23
	odoratum	Gros Michel
	odoratum	Williams
	odoratum	Yangambi Km 5
Canary Islands, Spain		
VCG 0120/15	odoratum	FHIA-03
	odoratum	FHIA-23
	odoratum	Grande Naine (AAA)
	odoratum	PV 03-44
	odoratum	Williams
	odoratum	Yangambi Km 5
VCG 0120	odoratum	FHIA-01
Chiuju, Pingtung, Taiwan		
VCG 0121	odoratum	Cavendish
	odoratum	Gros Michel
	odoratum	PA 03.22
	odoratum	Pisang Mas
	odoratum	Pisang Mas
	odoratum	Yangambi Km 5
VCG 01213/16	odoratum	Bluggoe
	odoratum	FHIA-23
	odoratum	Gros Michel
	odoratum	PA 03.22
VCG 01216	odoratum	Pisang Ceylan
Kichwamba, Bushenyi District, Uganda		
VCG unknown - not Foc	?	Pisang Nangka
	?	Williams
	?	Yangambi Km 5

* P. Lilin has been found to be 3 x

Table 11a. Correlations (Pearson); only improved and local cultivars. All locations.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.074										
	0.389										
Days_pha	0.008	0.890									
	0.924	0.000									
F_height	0.533	-0.336	-0.438								
	0.000	0.000	0.000								
B_weight	0.615	0.350	0.198	0.172							
	0.000	0.000	0.022	0.031							
N_hands	0.559	0.442	0.314	0.115	0.904						
	0.000	0.000	0.000	0.159	0.000						
N_finger	0.620	0.273	0.097	0.246	0.912	0.934					
	0.000	0.001	0.269	0.002	0.000	0.000					
AW_fing	0.324	0.321	0.325	-0.141	0.611	0.431	0.283				
	0.000	0.000	0.000	0.079	0.000	0.000	0.000				
Infind-2	-0.318	0.050	0.071	-0.150	-0.473	-0.327	-0.291	-0.608			
	0.000	0.591	0.452	0.080	0.000	0.000	0.001	0.000			
D D T	-0.092	0.104	0.119	-0.296	0.323	0.193	0.146	0.452	-0.601		
	0.288	0.216	0.172	0.001	0.000	0.029	0.096	0.000	0.000		
Y L S	0.028	0.188	0.036	0.274	0.320	0.249	0.259	0.122	-0.296	0.525	
	0.748	0.024	0.677	0.001	0.000	0.005	0.003	0.163	0.001	0.000	
L E R	0.190	-0.301	-0.275	0.236	-0.091	0.050	0.103	-0.419	0.329	-0.398	0.011
	0.042	0.001	0.003	0.013	0.338	0.603	0.279	0.000	0.000	0.000	0.907

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest

F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits

AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11b. Correlations (Pearson); only improved and local cultivars. Cameroon.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.513										
	0.012										
Days_pha	0.522	0.970									
	0.013	0.000									
F_height	0.518	-0.162	-0.026								
	0.014	0.472	0.908								
B_weight	0.537	0.862	0.836	-0.078							
	0.010	0.000	0.000	0.731							
N_hands	0.423	0.834	0.851	-0.025	0.956						
	0.050	0.000	0.000	0.911	0.000						
N_finger	0.448	0.750	0.803	0.127	0.917	0.978					
	0.037	0.000	0.000	0.572	0.000	0.000					
AW_fing	0.499	0.610	0.450	-0.385	0.660	0.435	0.317				
	0.018	0.003	0.036	0.077	0.001	0.043	0.151				
Infind-2	-0.267	-0.746	-0.798	0.304	-0.908	-0.905	-0.825	-0.586			
	0.218	0.000	0.000	0.169	0.000	0.000	0.000	0.004			
D D T	0.190	0.650	0.756	-0.282	0.901	0.917	0.860	0.494	-0.952		
	0.385	0.001	0.000	0.204	0.000	0.000	0.000	0.019	0.000		
Y L S	0.452	0.870	0.863	-0.235	0.931	0.893	0.812	0.678	-0.922	0.848	
	0.030	0.000	0.000	0.292	0.000	0.000	0.000	0.001	0.000	0.000	
L E R	-0.449	-0.904	-0.869	0.345	-0.853	-0.775	-0.698	-0.706	0.719	-0.678	-0.834
	0.036	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest

F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits

AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11c. Correlations (Pearson); only improved and local cultivars. Costa Rica, plant crop.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.627 0.001										
Days_pha	0.673 0.000	0.902 0.000									
F_height	0.507 0.011	-0.231 0.277	-0.019 0.928								
B_weight	0.652 0.001	0.881 0.000	0.817 0.000	-0.212 0.321							
N_hands	0.522 0.009	0.872 0.000	0.723 0.000	-0.381 0.067	0.949 0.000						
N_finger	0.560 0.004	0.874 0.000	0.703 0.000	-0.325 0.122	0.954 0.000	0.981 0.000					
AW_fing	0.611 0.002	0.861 0.000	0.837 0.000	-0.224 0.294	0.967 0.000	0.892 0.000	0.874 0.000				
Infind-2	-0.716 0.000	-0.569 0.004	-0.680 0.000	-0.151 0.481	-0.755 0.000	-0.651 0.001	-0.621 0.001	-0.753 0.000			
D D T	0.394 0.056	0.226 0.288	0.461 0.023	0.133 0.535	0.469 0.021	0.361 0.083	0.296 0.160	0.496 0.014	-0.781 0.000		
Y L S	0.399 0.053	-0.184 0.390	0.151 0.483	0.604 0.002	0.072 0.739	-0.100 0.642	-0.145 0.499	0.116 0.589	-0.557 0.005	0.791 0.000	
L E R	-0.577 0.003	-0.902 0.000	-0.805 0.000	0.314 0.135	-0.881 0.000	-0.853 0.000	-0.857 0.000	-0.860 0.000	0.622 0.001	-0.282 0.182	0.127 0.554

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest

F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits

AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11d. Correlations (Pearson); only improved and local cultivars. Costa Rica, ratoon.

	Pl_Height	F_height	B_weight	N_hands	N_finger	AW_fing
Pl_Height						
F_height	0.848 0.000					
B_weight	0.353 0.083	-0.069 0.743				
N_hands	0.237 0.254	-0.213 0.306	0.928 0.000			
N_finger	0.260 0.210	-0.194 0.352	0.934 0.000	0.990 0.000		
AW_fing	0.367 0.071	0.231 0.266	0.584 0.002	0.281 0.173	0.275 0.184	
Infind-2	-0.602 0.001	-0.462 0.020	-0.263 0.204	-0.236 0.256	-0.212 0.309	-0.163 0.436

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest
F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits
AW_fing: Average weight of fruits

Table 11e Correlations (Pearson); only improved and local cultivars. Honduras.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.834										
	0.000										
Days_pha	0.786	0.977									
	0.000	0.000									
F_height	0.436	0.052	0.105								
	0.033	0.810	0.627								
B_weight	0.878	0.803	0.705	0.154							
	0.000	0.000	0.000	0.473							
N_hands	0.804	0.817	0.716	-0.079	0.946						
	0.000	0.000	0.000	0.714	0.000						
N_finger	0.859	0.857	0.756	-0.001	0.959	0.987					
	0.000	0.000	0.000	0.998	0.000	0.000					
AW_fing	0.604	0.353	0.362	0.684	0.566	0.317	0.344				
	0.002	0.091	0.082	0.000	0.004	0.131	0.100				
Infind-2	0.278	0.277	0.212	-0.208	0.149	0.300	0.319	-0.316			
	0.179	0.180	0.319	0.330	0.488	0.154	0.128	0.132			
D D T	-0.869	-0.879	-0.798	-0.129	-0.900	-0.903	-0.932	-0.389	-0.257		
	0.000	0.000	0.000	0.547	0.000	0.000	0.000	0.060	0.215		
Y L S	-0.256	-0.102	0.066	0.224	-0.228	-0.361	-0.350	0.305	-0.684	0.334	
	0.217	0.629	0.760	0.292	0.284	0.084	0.093	0.148	0.000	0.102	
L E R	-0.417	-0.463	-0.579	-0.064	-0.286	-0.254	-0.269	-0.310	-0.129	0.181	-0.064
	0.038	0.020	0.003	0.768	0.175	0.230	0.203	0.140	0.540	0.388	0.760

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest
F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits
AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11f. Correlations (Pearson); only improved and local cultivars. Phillipines.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.219										
	0.305										
Days_pha	0.158	0.861									
	0.460	0.000									
F_height	0.448	-0.442	-0.298								
	0.032	0.035	0.168								
B_weight	0.454	0.361	0.559	0.173							
	0.034	0.099	0.007	0.441							
N_hands	0.155	0.399	0.557	-0.159	0.832						
	0.492	0.066	0.007	0.480	0.000						
N_finger	0.275	0.377	0.536	-0.102	0.770	0.884					
	0.215	0.084	0.010	0.653	0.000	0.000					
AW_fing	0.484	0.229	0.412	0.318	0.825	0.484	0.376				
	0.023	0.306	0.057	0.149	0.000	0.023	0.085				
Infind-2	-0.429	0.468	0.481	-0.509	-0.138	-0.006	0.088	-0.352			
	0.037	0.021	0.017	0.013	0.539	0.980	0.698	0.109			
D D T	0.241	-0.226	0.052	0.495	0.367	0.180	0.108	0.501	-0.549		
	0.280	0.313	0.817	0.022	0.111	0.447	0.651	0.025	0.008		
Y L S	0.122	-0.206	-0.060	0.551	0.519	0.321	0.257	0.548	-0.421	0.545	
	0.587	0.358	0.792	0.010	0.019	0.168	0.273	0.012	0.051	0.007	
L E R	0.214	-0.039	-0.260	0.187	-0.213	-0.340	-0.305	-0.115	-0.040	-0.378	0.046
	0.316	0.858	0.220	0.394	0.341	0.121	0.168	0.611	0.852	0.075	0.834

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest
F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits
AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11g. Correlations (Pearson); only improved and local cultivars. Tonga.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	-0.117										
	0.632										
Days_pha	-0.118	0.319									
	0.630	0.158									
F_height	0.459	-0.504	0.013								
	0.056	0.028	0.957								
B_weight	0.096	0.904	0.185	-0.268							
	0.694	0.000	0.421	0.267							
N_hands	-0.076	0.885	0.232	-0.331	0.912						
	0.756	0.000	0.312	0.167	0.000						
N_finger	0.060	0.885	0.239	-0.282	0.946	0.981					
	0.806	0.000	0.296	0.242	0.000	0.000					
AW_fing	0.167	0.556	-0.059	-0.147	0.697	0.394	0.438				
	0.494	0.009	0.799	0.549	0.000	0.077	0.047				
Infind-2	-0.115	-0.792	-0.438	-0.075	-0.718	-0.653	-0.674	-0.475			
	0.640	0.000	0.047	0.759	0.000	0.001	0.001	0.030			
D D T	0.108	0.769	0.384	0.155	0.701	0.565	0.614	0.545	-0.809		
	0.659	0.000	0.086	0.527	0.000	0.008	0.003	0.011	0.000		
Y L S	-0.031	0.749	0.397	0.210	0.662	0.557	0.581	0.489	-0.804	0.937	
	0.900	0.000	0.074	0.389	0.001	0.009	0.006	0.024	0.000	0.000	
L E R	0.145	0.221	0.240	0.192	0.044	0.115	0.091	-0.146	-0.205	0.199	0.251
	0.553	0.288	0.295	0.430	0.849	0.620	0.696	0.528	0.338	0.340	0.226

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest

F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits

AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

Table 11h. Correlations (Pearson); only improved and local cultivars. Uganda.

	Pl_Height	Days_psh	Days_pha	F_height	B_weight	N_hands	N_finger	AW_fing	Infind-2	D D T	Y L S
Days_psh	0.474										
	0.022										
Days_pha	0.384	0.947									
	0.104	0.000									
F_height	*	*	*								
		*	*	*							
B_weight	0.499	0.639	0.548	*							
	0.029	0.002	0.012	*							
N_hands	0.284	0.863	0.881	*	0.635						
	0.286	0.000	0.000	*	0.006						
N_finger	0.288	0.324	0.183	*	0.752	0.190					
	0.231	0.164	0.439	*	0.000	0.465					
AW_fing	0.368	0.725	0.730	*	0.710	0.860	0.100				
	0.121	0.000	0.000	*	0.000	0.000	0.676				
D D T	0.225	0.225	0.240	*	0.345	0.476	0.261	0.243			
	0.301	0.291	0.309	*	0.137	0.053	0.266	0.302			
Y L S	0.377	0.848	0.790	*	0.692	0.801	0.549	0.553	0.555		
	0.076	0.000	0.000	*	0.001	0.000	0.012	0.011	0.004		

Cell Contents: Correlation P-Value
Pl_Height: Plant height
Days_psh: number of Days from planting to shooting
Days_pha: number of Days from planting to harvest

F_height: Follower's height
B_weight: Bunch weight
N_hands: Number of hands
N_finger: Number of fruits

AW_fing: Average weight of fruits
Infind-2: Infection index at stage 2
DDT: Disease development time
YLS: Youngest leaf spotted
LER: Leaf emission rate

List of Acronyms

ANOVA	Analysis of Variance
APT	Arbitrary Primer Technology
β	Beta (Regression slope)
BPI	Bureau of Plant Industry
BS	Black Sigatoka
CEMSA	Centro de Mejoramiento de Semillas Aganicus, Cuba
CGTCV	Giant Cavendish Tissue Culture Variant
CNPMF	Centro Nacional de Pesquisa de Mandioca e Fruticultura
CORBANA	Corporación Bananera Nacional
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
CRBP	Centre de recherches régionales sur bananiers et plantains
CRC	Cooperative Research Centre
CRD	Complete Randomised Design
DAF	DNA Amplification Fingerprint
DDT	Disease Development Time
DPI	Department of Primary Industries
EMBRAPA	Empresa Brasiliera de Pesquisa Agropecuaria
FHIA	Fundación Hondureña de Investigación Agrícola
Foc	*Fusarium oxysporum* f. sp. *cubense*
ICIA	Instituto Canario de Investigaciones Agrarias
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
II	Infection Index
IMTP	International *Musa* Testing Programme
INIVIT	Instituto de Investigaciones en Viandes Tropicales
ITC	INIBAP Transit Centre
ITSC/ARC	Institute for Tropical and Subtropical Crops / Agricultural Research Council
KUL	Katholieke Universiteit Leuven
MAFF	Ministry of Agriculture, Fisheries and Forestry
MARDI	Malaysian Agricultural Research and Development Institute
NARO	National Agricultural Research Organization
NARS	National Agricultural Research Systems
P	Probability
PA	(Prefix on cultivar name meaning) Prata aña
PCR	Polymerase Chain Reaction
PV	(Prefix on cultivar name meaning) Pacovan
R^2	Correlation Coefficient
RAPDS	Random Amplified Polymorphic DNAs
RCBD	Randomised Complete Block Design
RIF	Research Institute for Fruits
SH	(Prefix on cultivar name meaning) Selected Hybrid
TBRI	Taiwan Banana Research Institute
UNDP	United Nations Development Programme
VCG	Vegetative Compatibility Group
YLS	Youngest Leaf Spotted
YS	Yellow Sigatoka

List of figures

Annex I. Characterization of *Fusarium oxysporum* f.sp. *cubense* from IMTP Phase II sites

Natalie Y. Moore
QDPI, 80, Meiers Road, Indooroopilly, QLD 4068, Australia

Introduction

Fusarium wilt or Panama disease is caused by the soil-inhabiting pathogen *Fusarium oxysporum* f.sp. c*ubense* (*Foc*). The first report of *Foc* was from Australia in 1874 but it became epidemic in Central America in 1890 (Panama). In 1962, Stover speculated that *Foc* coevolved with edible bananas and their primitive diploid progenitors (*Musa acuminata* and *M. balbisiana*) in southeast Asia. It is now widely acknowledged that *Foc* originated in Asia and was subsequently dispersed from this region in planting material (Buddenhagen 1990, Simmonds 1962, 1966). The affected cultivars have diverse genotypes and are widespread geographically in banana-growing regions of Africa, Asia, Australia, the South Pacific and Latin America.

Fusarium wilt severely affects local and subsistence production of bananas, plantains and cooking bananas which are an important source of food throughout Africa, Asia and Oceania. There is a need for research on the ecology and diversity of Fusarium wilt in these affected areas. Such information would provide the basis for better disease control through the ability to identify what populations of the pathogen are present prior to planting to enable growers to make an informed decision as to whether or not to plant, and if so, which varieties.

In Indonesia, large export industries based on Cavendish varieties have been devastated by Fusarium wilt. These varieties are also seriously affected in other tropical production areas such as Malaysia and the Northern Territory (Australia). Subtropical production areas of South Africa, Canary Islands, Taiwan and Australia are also seriously affected by this disease. Recently, *Foc* was reported in Papua New Guinea, where a single wilted cooking banana plant of an undetermined cultivar was found at a site less than 20 km from the border of Irian Jaya. The pathogen was probably introduced with the movement of planting material as there is virtually uncontrolled movement of people and produce across the northern coastal border (Shivas and Philemon 1996). This occurrence emphasises the need to observe quarantine principles, especially in areas of the world that remain free from the disease (including countries bordering the Mediterranean, islands of the South Pacific, Somalia).

Disease control is based primarily on quarantine and host resistance, hence the necessity to understand pathogen diversity. Assessing the genetic diversity and variability in pathogen populations is a necessary component in the selection or breeding of banana cultivars with durable resistance to Fusarium wilt. Several different techniques have been used to study biodiversity in *Foc* populations. Vegetative compatibility group (VCG) analysis, the production of volatile compounds on starch substrate and molecular genetic techniques (RAPD-PCR, DAF) have proved to be reliable *in vitro* techniques for classification of isolates of *Foc*. Worldwide, there are at least 21 VCGs of *Foc* (Pegg *et al.* 1993, 1996, Bentley *et al.* 1995, Ploetz 1990).

The evaluation of resistant *Musa* cultivars is the primary objective of the International *Musa* Testing Programme (IMTP). Hybrids produced by FHIA (FHIA-01, FHIA-02, FHIA-03, FHIA-17, FHIA-23), CNPMF/EMBRAPA (PV 03.44, PA 03.22), TBRI (GCTCV 119, GCTCV 215), other varieties (including Cavendish cv. Williams, Burro CEMSA, Pisang

Ceylan, Pisang Berangan, Bluggoe, Ney Poovan, Gros Michel, Saba, Pisang Nangka, Yangambi Km 5) and five diploids (Pisang Mas, Rose, Pisang Jari Buaya, Pisang Lilin, Calcutta IR 124) were evaluated in IMTP Phase II trials. Thirteen countries agreed to participate in the field evaluation of 22 accessions of *Musa* germplasm for reaction to Fusarium wilt. Specimens from wilted plants were prepared for isolation and analysis of *Foc* according to INIBAP guidelines (Jones 1994, Moore *et al.* 1995).

The data collected from these field trials provide information on global diversity of *Foc* as well as the behaviour of pathogenic variants and reaction of *Musa* germplasm under various environmental conditions.

Objectives

The objectives of this study were to:

1. analyse isolates of *Foc* recovered from specimens of wilted germplasm from IMTP Phase II sites using VCG, volatile production and DNA fingerprinting;
2. communicate results of analysis to site coordinators and Dr Gisella Orjeda, the *Musa* Genetic Improvement Scientist at INIBAP; and
3. offer interpretation of results and suggestions for improvement for analysis of specimens from future trials.

Techniques used to characterise isolates

Samples of dried discoloured vascular tissue from the pseudostems of infected plants were prepared by staff at each site and sent to the Plant Pathology Unit, DPI, Indooroopilly, Qld, Australia for analysis (Jones 1994, Moore *et al.* 1995). *Foc* was isolated from affected tissue and monoconidial cultures prepared for each isolate. Vegetative compatibility analysis, volatile production and DNA fingerprinting were used to characterise isolates of *Foc.* These techniques are briefly described below.

Vegetative compatibility group (VCG)

Vegetative compatibility characterises groups of isolates based on the genetic relationships within the fungal populations rather than host-pathogen interaction. This technique differentiates isolates that have identical alleles at each of the loci that govern heterokaryon formation and thus vegetative compatibility. These loci are referred to as vegetative incompatibility (*vic*) or heterokaryon (*het*) loci. On the basis of heterokaryon formation, isolates of *Foc* can be divided into genetically distinct groups known as vegetative compatibility groups (VCGs) (Correll *et al.* 1987). The technique developed by Puhalla (1985) is based on the generation of nitrogen non-utilising (*nit*) mutants, and enables heterokaryon formation to be scored macroscopically, making VCG analysis amenable to population studies.

Volatile production

Brandes (1919) found that isolates of *Foc* grown on steamed rice either produced or did not produce a characteristic volatile odour. Stover (1962) also used volatile compounds to differentiate strains of this pathogen. Stover assigned isolates to either the 'odoratum' or 'inodoratum' group, based on the presence or absence of volatile substances. This technique has been used to characterise Australian and Asian isolates of *Foc* (Moore *et al.* 1991, Pegg *et al.* 1993, 1996). These studies indicated that the production of volatile compounds on rice medium could be used to differentiate between strains of *Foc.* There was absolute correlation between the production of volatile substances and VCG. Volatile analysis is a simple and inexpensive method of characterising isolates of *Foc* based on the biochemistry of cultures *in vivo*.

DNA fingerprinting

Arbitrary Primer Techniques (RAPD-PCR and DAF) have been used to generate genome-specific DNA fingerprints to further characterise isolates of *Foc* (Bentley and Bassam 1994, Bentley *et al*. 1995). Using these DNA fingerprinting techniques, it is possible to determine the genetic similarity between isolates within each VCG and the genetic relatedness among VCGs. Molecular analysis is a useful tool for characterising isolates where VCG is undetermined or unknown.

Characterisation of *Foc* at each site

Australia

Two IMTP field trials were conducted in Australia, one situated at Cudgen, New South Wales (Site No. 1) and the other at Wamuran, Queensland (Site No. 2). These trials were managed by Ken Pegg and Peter Langdon respectively.

Of the 11 isolates of *Foc* characterised from Cudgen, New South Wales, nine isolates belong to the known race 1 VCG 0124. All isolates in VCG 0124 and the two isolates of undetermined VCG produced non-volatile compounds on rice substrate and belong to the 'inodoratum' group. As isolates in the same VCG generally belong to the same volatile production group, the undetermined VCG isolates are probably race 1 (Table 1). DNA analysis is being conducted to verify the VCG of these isolates.

Table 1. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP site No. 1 at Cudgen, New South Wales, Australia.

Isolate	Cultivar	Volatile production
VCG 0124		
24467	Gros Michel (AAA)	inodoratum
24468	Ney Poovan (AB)	inodoratum
24469	Calcutta IR 124 (AAw)	inodoratum
24470	FHIA-02 (AAAB)	inodoratum
24471	Pisang Ceylan (AAB)	inodoratum
24472	Gros Michel (AAA)	inodoratum
24473	Bluggoe (ABB)	inodoratum
24485	Pisang Ceylan (AAB)	inodoratum
24486	Gros Michel (AAA)	inodoratum
VCG Undetermined		
24474	Bluggoe (ABB)	inodoratum
24487	FHIA-02 (AAAB)	inodoratum

Ten isolates of *Foc* from the IMTP site at Wamuran, Queensland were characterised using vegetative compatibility analysis and volatile production and all belong to the known race 4 VCG 0120. All produced volatile compounds on rice and belong to the 'odoratum' group (Table 2).

Table 2. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP site No. 2 at Wamuran, Queensland, Australia.

Isolate	Cultivar	Volatile production
VCG 0120		
24475	FHIA-03 (AABB)	odoratum
24476	Bluggoe (ABB)	odoratum
24477	Gros Michel (AAA)	odoratum
24478	Pisang Mas (AA)	odoratum
24479	FHIA-23 (AAAA)	odoratum
24480	Pisang Mas (AA)	odoratum
24481	Igisahira	odoratum
24482	Gros Michel (AAA)	odoratum
24483	Bluggoe (ABB)	odoratum
24484	FHIA-23 (AAAA)	odoratum

Brazil

The IMTP trial site is situated at Cruz das Almas, Bahia (Site No. 3) and managed by Dr A. Pires de Matos. Seventeen samples were received from 26 March 1997 to 8 October 1997.

Of the seven isolates of *Foc* successfully recovered from the samples, five belonged to the known race 1 VCGs 0124 and 0125. Two isolates were of undetermined VCG. However, when cultured on sterilised rice, none of the isolates produced volatile compounds and therefore belong to the ‘inodoratum’ group. As isolates in the same VCG generally belong to the same volatile production group, the isolates of undetermined VCG are likely race 1. Isolates of undetermined VCG are also being analysed using molecular techniques to determine DNA fingerprint.

Table 3. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 3, Brazil.

Isolate	Cultivar	Volatile production
VCG 0124		
Brazil 1	Bluggoe (ABB)	inodoratum
Brazil 2	Bluggoe (ABB)	inodoratum
Brazil 6	Bluggoe (ABB)	inodoratum
Brazil 7	Bluggoe (ABB)	inodoratum
VCG 0125		
Brazil 5	Bluggoe (ABB)	inodoratum
VCG Undetermined		
Brazil 3	FHIA-03 (AABB)	inodoratum
Brazil 2	Bluggoe (ABB)	inodoratum

India

The IMTP trial site is situated at NRCB, Tamil Nadu State (Site No. 15), APAU and it is managed by Dr H.P. Singh. Eight samples were received on 17 February 1997.

Of the six isolates of *Foc* from India, four isolates belonged to the known race 1 VCGs 0124/5 and 0125. One isolate, India 20, was found to be a race 4 VCG 01213/16 and was the only isolate that produced volatile compounds, placing it in the ‘odoratum’ group. Ideally, trial sites should not contain populations of *Foc* of different races, and more importantly race 4 has not been reported from India before (see discussion). At the time of writing, one isolate was of undetermined VCG. This isolate was from cultivar Silk/Rasthali(AAB) and is probably a race 1 VCG as no volatile compounds were produced when cultivated on sterilised rice (Table 4).

Table 4. Vegetative compatibility and volatile production of strains of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 15, India.

Isolate	Cultivar	Volatile production
VCG 0124/5		
India 18	Pisang Awak (ABB)	inodoratum
VCG 0125		
India 19	Pisang Awak (ABB)	inodoratum
India 22	Pisang Awak (ABB)	inodoratum
India 23	Silk/Rasthali (AAB)	inodoratum
VCG 01213/16		
India 20	Silk/Rasthali (AAB)	odoratum
VCG Undetermined		
India 21	Silk/Rasthali (AAB)	inodoratum

Indonesia

The IMTP trial site is situated at Solok, in West Sumatra (Site No. 19) and is managed by Mrs Tutik Setyawati. Fifteen samples were received during the period 29 November 1996 to 16 June 1997.

Of the 12 isolates of *Foc* successfully recovered from the samples, 10 belong to the known race 4 VCG 01213/16. An isolate belonging to a second VCG was identified at this site, VCG 01219. Comparison of DNA fingerprints generated for *Foc* has subdivided isolates into two major groups (Bentley *et al.* 1995). Both of the VCGs identified at this site belong to Group 1 which contain all the 'odoratum' isolates of presumed rate 4 pathotype. However, the pathogenic potential of isolates in VCG 01219 on Cavendish cultivars is unknown. It is not desirable to have mixed populations (VCGs) of *Foc* at an evaluation site (see discussion). Indo 201 which was of undetermined VCG produced volatile compounds and belongs to the ‘odoratum’ group suggesting that it is also a "race 4" VCG (Table 5).

Table 5. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 19, Indonesia.

Isolate	Cultivar	Volatile Pproduction
VCG 01213/16		
Indo 131	Pisang Nangka	odoratum
Indo 133	Bluggoe	odoratum
Indo 134	PV 03-44	odoratum
Indo 135	Yangambi Km 5	odoratum
Indo 136	Pisang Mas	odoratum
Indo 137	GCTCV 215	odoratum
Indo 138	Pisang Mas	odoratum
Indo 139	FHIA-23	odoratum
Indo 140	Pisang Ceylan	odoratum
Indo 141	Williams	odoratum
VCG 01219		
Indo 202	Kepok	odoratum
VCG Undetermined		
Indo 201	FHIA-17	odoratum

Malaysia

Two IMTP trial sites were established in Malaysia and managed by Mrs S.H. Jamaluddin. One site is situated in Serdang, Selangor (Site No. 21) and the other is located on a commercial plantation in Johor (Site No. 22). Seventeen samples were received from both sites during the period 27 November 1996 to 4 January 1997.

Ten isolates of *Foc* from site No. 21 in Selangor were characterised using vegetative compatibility analyses and volatile production and all belong to the known "tropical" race 4 VCG 01213/16. All isolates produced volatile compounds on sterilised rice and belong to the ‘odoratum’ group (Table 6).

Four isolates of *Foc* from site No. 22 at Johor were characterised and also belonged to VCG 01213/16 and the odoratum group (Table 7).

Table 6. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 21 at Selangor, Malaysia.

Isolate	Cultivar	Volatile production
VCG 01213/16		
Mal 102	Burro CEMSA (ABB)	odoratum
Mal 103	Pisang Mas (AA)	odoratum
Mal 105	FHIA-17 (AAAA)	odoratum
Mal 106	Pisang Ceylan (AAB)	odoratum
Mal 107	FHIA-23 (AAAA)	odoratum
Mal 109	PV 03-44 (AAAB)	odoratum
Mal 110	Pisang Berangan (AA)	odoratum
Mal 111	Bluggoe (ABB)	odoratum
Mal 112	Williams (AAA)	odoratum
VCG 01216		
Mal 104	Yangambi Km 5 (AAA)	odoratum

Table 7. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 22 at Johor, Malaysia.

Isolate	Cultivar	Volatile production
VCG 01213/16		
Mal 100	FHIA-17 (AAAA)	odoratum
Mal 101	Pisang Mas (AA)	odoratum
Mal 113	Pisang Awak (ABB)	odoratum
VCG 01213		
Mal 99	Burro CEMSA (ABB)	odoratum

Philippines

Two IMTP trial sites were established in The Philippines, one situated at Bago Oshiro, Davao City and the other at Davao del Norte, Mindanao. These sites were managed by Dr Lydia V. Magnaye. Two hundred and eighty nine samples were received from March 1996 to 15 July 1997 but few yielded *Foc*.

Of the four isolates of *Foc* successfully recovered from the samples from Davao City characterised using vegetative compatibility analyses and volatile production, one belongs to the known race 1 VCG 0123. The isolates did not produce volatile substances when cultured on rice substrate, placing them in the 'inodoratum' group. The three isolates of undetermined VCG were all non-volatile and belong to the 'inodoratum' group and are probably race 1 VCGs. *Foc* was only recovered from variety Latundan (AAB) (Table 8).

Of the four isolates of *Foc* from Davao del Norte, Mindanao, two belonged to the known race 4 VCG 0122 and the 'odoratum' group. The two isolates of undetermined VCG produced volatile compounds and are probably also race 4 VCG. *Foc* was isolated from three banana varieties, namely, Cavendish (AAA), Pisang Lilin (AA) and Pisang Ceylan (AAB) (Table 9).

The isolates of undetermined VCG are currently being analysed for DNA profile to determine to which VCG they belong.

Table 8. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from Bago Oshiro, Davao City, Philippines.

Isolate	Cultivar	Volatile production
VCG 0123		
Phil 37	Latundan (AAB)	inodoratum
VCG Undetermined		
Phil 38	Latundan (AAB)	inodoratum
Phil 39	Latundan (AAB)	inodoratum
Phil 49	Latundan (AAB)	inodoratum

Table 9. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from Davao del Norte, Mindanao, Philippines.

Isolate	Cultivar	Volatile production
VCG 0122		
Phil 36	Cavendish (AAA)	odoratum
Phil 48	Pisang Lilin (AA)	odoratum
VCG Undetermined		
Phil 47	Pisang Lilin (AA)	odoratum
Phil 52	Pisang Ceylan (AAB)	odoratum

South Africa

The IMTP trial site No. 30 is situated in Hazyview, Eastern Transvaal and is managed by Dr Z. De Beer. Fifty two samples were received from this site during the period of October to December 1996.

All of the 19 isolates of *Foc* recovered from samples from South Africa belonged to the known race 4 VCGs 0120 and 0120/15 and produced volatile compounds, placing them in the 'odoratum' group (Table 10).

Table 10. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 30, South Africa.

Isolate	Cultivar	Volatile production
VCG 0120		
SA 1	FHIA-03 (AABB)	odoratum
SA 2	Bluggoe (ABB)	odoratum
SA 3	FHIA-03 (AABB)	odoratum
SA 4	Chinese Cavendish (AAA)	odoratum
SA 6	GCTCV 215 (AAA)	odoratum
SA 7	Burro CEMSA (ABB)	odoratum
VCG 0120/15		
SA 5	FHIA-03 (AABB)	odoratum
SA 8	Bluggoe (ABB)	odoratum
SA 10	FHIA-03 (AABB)	odoratum
SA 11	Yangambi Km 5 (AAA)	odoratum
SA 12	Williams (AAA)	odoratum
SA 13	Chinese Cavendish (AAA)	odoratum
SA 14	FHIA-17 (AAAA)	odoratum
SA 15	FHIA-23 (AAAA)	odoratum
SA 16	FHIA-17 (AAAA)	odoratum
SA 17	FHIA-17 (AAAA)	odoratum
SA 18	FHIA-23 (AAAA)	odoratum
SA 19	FHIA-23 (AAAA)	odoratum
SA 20	Gros Michel (AAA)	odoratum

Spain (Canary Islands)

The IMTP trial is situated at Valle de Guerra, Tenerife, Canary Islands (Site No. 31) and is managed by Dr J. Hernandez. Thirty nine samples were received from 12 December 1996 to 12 March 1997.

All of the 16 isolates of *Foc* recovered belonged to the known race 4 VCGs 0120 and 0120/15. All isolates produced volatile compounds and belonged to the 'odoratum' group (Table 11).

Table 11. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP site No. 31, Canary Islands, Spain.

Isolate	Cultivar	Volatile production
VCG 0120/15		
CI 1	Yangambi Km 5 (AAA)	odoratum
CI 3	Grande Naine (AAA)	odoratum
CI 6	FHIA-23 (AAAA)	odoratum
CI 7	FHIA-23 (AAAA)	odoratum
CI 8	Williams (AAA)	odoratum
CI 9	Williams (AAA)	odoratum
CI 11	Williams (AAA)	odoratum
CI 12	Williams (AAA)	odoratum
CI 13	Williams (AAA)	odoratum
CI 14	Williams (AAA)	odoratum
CI 15	Williams (AAA)	odoratum
CI 16	Williams (AAA)	odoratum
CI 17	Williams (AAA)	odoratum
CI 19	PV 03-44 (AAAB)	odoratum
CI 20	FHIA-03 (AABB)	odoratum
VCG 0120		
CI 21	FHIA-01	odoratum

Taiwan

The IMTP trial is situated at Chiuju, Pingtung, Taiwan (Site No. 32) and is managed by Dr Ching-Yan Tang. Forty eight samples were received from December 1996 to July 1997.

Of the 16 isolates of *Foc* from Taiwan characterised using vegetative compatibility analyses and volatile production, 12 belonged to the known race 4 VCGs 0121 and 01213/16. Two isolates, Taiwan 8 and 12, were characterised using DNA fingerprinting revealing that they also belonged to VCG 0121. All isolates produced volatile products placing them in the ‘odoratum’ group (Table 12).

Uganda

IMTP trial site No. 37 is situated at Kichwamba, Bushenyi District, Uganda. This site is managed by Dr Africano Kangire. Fifteen samples were received from this site during November 1996.

Only three isolates of *Fusarium* were isolated and they were of unusual morphology and atypical volatile production. These isolates were not able to be characterised using vegetative compatibility analyses or volatile production (see discussion). We are still in the process of conducting DNA analyses of these isolates (Table 13).

Table 12. Vegetative compatibility and volatile production of isolates of *Fusarium oxysporum* f.sp. *cubense* from IMTP Site No. 32, Taiwan.

Isolate	Cultivar	Volatile production
VCG 0121		
Taiwan 1	PA 03.22 (AAAB)	odoratum
Taiwan 2	PA 03.22 (AAAB)	odoratum
Taiwan 4	Pisang Mas (AA)	odoratum
Taiwan 6	Gros Michel (AAA)	odoratum
Taiwan 8	Gros Michel (AAA)	odoratum
Taiwan 12	Pisang Mas (AA)	odoratum
Taiwan 14	Yangambi Km5 (AAA)	odoratum
Taiwan 16	Cavendish (AAA)	odoratum
Taiwan 17	Cavendish (AAA)	odoratum
VCG 01213/16		
Taiwan 3	PA 03.22 (AAAB)	odoratum
Taiwan 5	Gros Michel (AAA)	odoratum
Taiwan 11	FHIA-23 (AAAA)	odoratum
Taiwan 15	Bluggoe (ABB)	odoratum
VCG 01216		
Taiwan 7	Pisang Ceylan (AAB)	odoratum
VCG Undetermined		
Taiwan 9	Saba (BBB/ABB)	odoratum
Taiwan 13	Pisang Nangka (AAB)	odoratum

Table 13. Vegetative compatibility and volatile production of isolates of *Fusarium* from IMTP Site No. 37, Uganda.

Isolate	Cultivar	Volatile production
VCG Unknown - Not *Foc*		
Uganda 2	Yangambi Km5 (AAA)	?
Uganda 3	Pisang Nangka (AAB)	?
Uganda 4	Williams (AAA)	?

Discussion

Results of VCG, volatile and DNA analysis of isolates of *Foc* from diseased plants in the IMTP trials generally confirmed the strain of the pathogen expected to be present at the site and its pathogenicity to the affected cultivars. At the time of writing, DNA analysis was continuing on several isolates that did not give positive results in initial VCG tests. The results of these analyses will be communicated to the Genetic Improvement Scientist at INIBAP. Interpretation of results of resistance evaluations will not be attempted in this report. Rather the following points aim to highlight anomalies or problem areas that may need to be rectified for improved results in analyses of *Foc* from future IMTP trials.

Quality of samples

In total, 523 samples were received and processed at the Indooroopilly laboratories. From these, 115 isolates of *Foc* and 3 isolates of an unknown *Fusarium* species were successfully recovered. If the extraordinarily high number of samples from the Philippines (289) which only yielded 4 isolates of *Foc*, are disregarded, the recovery rate of 111 isolates of *Foc* from 234 samples can be considered as acceptable. The technique of allowing excised, discoloured vascular strands to dry naturally in blotting paper for a few days before posting by express air mail has been successful in allowing recovery of the pathogen for analysis. It may be useful to provide collaborators in future trials with a more detailed description of the correct procedures for preparation of specimens which could include photographic examples of correctly prepared vascular material. The samples received from the Philippines did not appear to be whole lengths of vascular material but were often rather small flecks of dried tissue inconsistent with infected vascular material. Much effort was made to communicate with collaborators when material was received in substandard condition or did not yield any cultures *Foc*. Unfortunately the problem with the samples from the Philippines could not be rectified. One wonders about the severity of disease at these sites.

At the time of writing, no samples had been received from IMTP site number 10 in Cuba, site number 12 in Honduras, site numbers 15 and 17 in India, or site numbers 18 and 20 in Indonesia.

The isolates recovered from specimens sent from site number 37 in Uganda were not *Foc* although isolates recovered from non-IMTP specimens from wilted banana plants in surrounding districts confirmed the presence of the race 1 VCG 0124/5 (N. Moore, unpublished data).

Mixed populations of Foc *at testing sites*

In general VCG determinations of isolates confirmed the strain of *Foc* that was expected from each site given prior VCG identifications. However, the identification of an isolate in VCG 01219 from site No. 19 in Indonesia (supposedly a VCG 01213/16 site) and of an isolate in VCG 01213 from site No. 15 in India (a site supposed to contain only race 1 VCGs 0124/5) is cause for concern. Where different strains of the pathogen are present in the same testing site, the reliability of resistance evaluation data is compromised. Although VCG 01219 belongs to the same broad group as VCG 01213/16 based on DNA fingerprints (Bentley *et al.* 1995) and volatile production (Moore *et al.* 1991), the pathogenic potential of isolates in VCG 01219 on Cavendish cultivars is unknown. A germplasm collection is located nearby to site No. 19 and this could possibly have caused cross-contamination as cultivars in the collection have been gathered from throughout the Indonesian islands as vegetative material (i.e. suckers) which may have inadvertently carried other strains of *Foc* to the Solok site. Analysis of isolates from diseased plants in the collection could confirm this hypothesis. This VCG of *Foc* has frequently been recorded from locations throughout Indonesia (N. Moore, unpublished data).

Proximity to a germplasm collection may also explain the presence of isolate in VCG 01213 at site No. 15 in India but the author is unable to confirm this, having not visited the site. It is strongly recommended that more samples are collected for analysis from plants at this site and from any wilted banana plants growing nearby to determine the possible source of the cross-contamination and the extent of the distribution of this strain of the pathogen. The presence of VCG 01213 of *Foc* in India has serious implications for local farmers since this strain has not previously been recorded in India and could be expected to be pathogenic on the local banana varieties, including Cavendish. Local quarantine measures including *in situ* destruction of the affected plants (guidelines can be provided if required) and preventing removal of suckers from this site are recommended to contain the spread of this strain of the pathogen. If this strain of the pathogen is not found to be widespread in surrounding areas, no soil or planting material should be allowed to be removed from the site and it is recommended that bananas not be planted on this site again to limit proliferation of this potentially devastating strain of the pathogen.

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Annex II. Characterisation of isolates

Methods

Vegetative compatibility analysis

(a) Generation of nitrate non-utilising mutants

Nitrate non-utilising (*nit*) mutants are generated using a technique developed by Cove (1976) and modified by Puhalla (1985) and Correll *et al*. (1987). For each isolate tested, small blocks of mycelium from a monoconidial culture which is grown on either PDA medium amended with streptomycin for 2 to 3 days or carnation leaf agar for periods of up to 14 days, are transferred to half strength potato sucrose medium amended with 1.5% potassium chlorate (KPS) and incubated at 25ºC. Chlorate-resistant mutants, which emerge as fast growing sectors from the restricted colonies on KPS medium after 7 to 12 days, are subcultured onto minimal medium (MM) to determine their status as nitrate non-utilising (*nit*) mutants.

(b) Determination of phenotype and storage of nit *mutants*

The phenotype of *nit* mutants is determined by the method of Correll *et al.* (1987) where mutants are assessed for growth on media containing different nitrogen sources. Mutants with *nit* 1 or *nit* 3 phenotypes from the isolates of unknown VCG are paired with Nit M mutants of known VCG.

Cultures of *nit* mutants are maintained by subculturing on MM and as dried colonised filter paper cultures, as previously described for wild type isolates (Correll *et al.* 1986). The Nit M tester mutants are also maintained as lyophilised carnation leaf agar cultures (Burgess *et al.* 1988).

(c) Vegetative compatibility tests

Complementation tests are conducted by placing small blocks of mycelium from several (at least 2 and up to 6) *nit* 1 or *nit* 3 mutants from the strain being tested onto MM plates, 10 to 15 mm apart from blocks of mycelium of Nit M mutants of known VCG. The paired cultures are incubated at 25ºC. After five days cultures are inspected for heterokaryon development along the line of contact between the mycelium of the *nit* mutants and the advancing margin of the tester Nit M Mutant. If no heterokaryon growth has developed after 14 days, the strains being paired are designated as vegetatively incompatible. When heterokaryon formation occurs between a new strain and a tester Nit M (usually within 8 days), that strain is assigned to the same VCG as the tester strain.

Volatile production analysis

For each isolate, two pieces (approximately 10 mm x 20 mm) of monoconidial culture which have been growing on carnation leaf agar for 5 to 8 days are used to inoculate flasks of sterile, steamed rice which are prepared in the following manner: 30 mL of white rice (e.g. "Sunwhite" long grain) and 90 mL of distilled water is added to 250 mL Erlenmeyer flasks which are plugged with cotton wool and covered with alufoil before being steamed at 103ºC for 1 hour on each of two consecutive days. The inoculated rice cultures are grown at 23-27ºC on the laboratory bench for 12 to 14 days before being assessed for volatile production.

DNA amplification fingerprinting (DAF)

DNA isolation

Isolates of *Fusarium oxysporum* f.sp. *cubense* are cultured on potato dextrose agar (PDA) at 28ºC for 2-4 days, then transferred into 250 mL Erlenmeyer flasks containing 200 mL of quarter strength potato dextrose broth (PDB) and incubated at room temperature for a further 7 days without shaking. Mycelium is harvested by filtration through Miracloth (Calbiochem Inc.) and stored at -70ºC until used for DNA extraction. To extract the DNA, 1 g of frozen mycelium is ground to a fine powder in liquid nitrogen and incubated overnight at 37ºC in 1 mL of DNA extraction buffer [2% sodium dodecyl sulfate (SDS), 40 mM ethylenediaminetetraacetic acid (EDTA), 40 mM sodium chlorite, 100 mM Tris-HCl (pH 8.0) and 25 mM diethyldithiocarbamic acid]. The suspension is deproteinized by extracting twice with an equal volume of phenol and once with an equal volume of chloroform:isoamylalcohol (24:1). DNA is precipitated by adding two volumes of ice-cold ethanol and 0.1 volumes 3 M sodium acetate (pH 5.4) and incubating at -20ºC for 2 hours. The precipitate is collected by centrifugation, washed with 70% ethanol and dried *in vacuo.* The pellet is resuspended in TE (10 mM Tris, 1 mM EDTA, pH 8.0) and the DNA concentration is determined spectrophotometrically in a 5 µL sample cuvette using a GeneQuant™ RNA/DNA Calculator (Pharmacia LKB Biochrom Ltd, Cambridge, England).

DNA amplification

Optimized DNA amplification reactions contain 25 ng of template DNA, 12 µM primer, 5 mM $MgCl_2$, 3 units of AmpliTaq® Stoffel Fragment DNA polymerase (Perkin Elmer, Norwalk, CT), 10 mM Tris (pH 8.3), 10 mM KC1, 200 µM of each dNTP, sterile distilled water to 20 µL, with a 20 µL paraffin oil overlay (BDH Chemicals, Kilsyth, Vic. Australia). Primer sequences are DINQ 5' CTG GCC CA 3', DJDH 5' ACC AGC CA 3', EHKJ 5' GCT CAC GA 3', HIRH 5' ACG TCC AC 3', ILOE 5' GAT GAG CC 3', IMBE 5' GAA ACG CC 3', IMBR CC 3', IMBR 5' GTA ACG 33', NRKI 5' CCT CGT GG 3', NROI 5' CCT GGT GG 3', and RKM1 5' CCC GTC GT 3'. To avoid pipetting errors and the pipetting of unnecessarily small volumes, 5x reagent stocks are prepared in bulk and stored in aliquots. A "master mix" of common reagents is prepared for each experiment (where possible) and total reaction volumes of not less than 20 µL is used. An accurately calibrated 1.00 m $MgCl_2$ solution (Sigma, St Louis, MI) is used to prepare 5 x buffer stocks of 50 mM Tris (pH 8.0), 50 mM KCl, and 25 mM $MgCl_2$.

Thermocycling

DNA amplification reactions are thermocycled using a PTC-100 programmable thermal controller (MJ Research Inc., Watertown, MA) having a 96-well block format in thin-wall 0.2 mL strip-cap tubes (Quantum Scientific, Milton, Qld, Australia). The PTC-100 monitors the block temperature only and had a heating ramp of about 1ºC/sec and a cooling ramp of about 0.8ºC/sec using a Peltier mechanism. The thermocycling protocol employs an initial melt cycle of 94ºC for 5 min followed by 35 2-phase amplification cycles having a melt phase of 94ºC for 30 sec and an annealing phase ramp of 52ºC, 51ºC, 50ºC, 49ºC and 48ºC programmed for 1 min at each temperature. A 72ºC extension phase is not used for amplification cycles. Following amplification, a final extension cycle of 72ºC for 5 min is used. Fastest transition times are used between all programmed steps.

Electrophoresis conditions

DNA amplification products (1µL) are separated by polyacrylamide gel electrophoresis (PAGE) using a Mini-Protean II apparatus (Bio-Rad Laboratories, Hercules, CA). The polyacrylamide gels are 10% T (T = total monomer) and 2%C (C = crosslinker) in 1x TBE buffer containing 10% urea and 5% glycerol. This gel mix is prepared as a stock sufficient to cast about 100 gels. Ammonium persulphate (10%) and N,N,N',N'-tetramethyl-ethylenediamine (TEMED) are added at 100µL/mL gel volume and 1 µL/mL gel volume respectively as polymerization catalysts. The 0.5 mm thick gels are cast on Gel Bond PAG backing film (FMC BioProducts, Rockland, ME). Gels are electrophoresed in 1x TBE running buffer at 300 V for 33 min. The molecular weight markers, AmpliSize™ (Bio-Rad Laboratories, Hercules, CA) and BioMarker™ Low (BioVentures Inc., Murfreesboro, TN), are used as DNA standards. DNA banding patterns are visualized by silver staining.

Data analysis

The genetic relatedness between the DNA fingerprint patterns of each isolate of *F. oxysporum* f.sp. *cubense* is determined using DNA fingerprinting analysis software from Bio-Rad Laboratories (Gel Compar v3.1; Applied Maths, Kortrijik, Belgium).

For computer-aided data analysis, original gels cast on backing film are scanned using a Bio-Rad Densitometer and Molecular Analyst v1.1.1 software. The gels are scanned using transmitted light through a medium grade calibration filter at maximum resolution (64 µM) with extra sharp edge enhancement in 8-bit grayscale. Gel scans are stored in a TIFF file format then converted to an optimized gel image. Conversion settings assign a track resolution of 700 points (pixels) for the area containing DNA fragments of between 1000 bp and 100 bp. The densitometric curve of each track is rescaled without smoothing. Two nodes (the top and bottom of each lane) are used to position a 10 pixel-thick sampling spline. Lanes are identified using search algorithm 1. A 50 pixel-thick bitmap of the original lane image (a "gel strip") is stored along with a densitometric curve. DNA profiles are normalized using a molecular weight marker lane as the common standard. For normalization, a lane resolution of 700 points is used, densitometric curves are not smoothed and the background is subtracted by applying the rolling disk algorithm with a 20 point intensity. Gels are aligned with the molecular weight reference markers and common (monomorphic) internal peaks (bands) of fingerprint lanes beginning with those adjacent to reference marker lanes. Only bands (DNA fragments) between 1000 bp and 100 bp are scored. To assign bands, Autosearch filters are used with a minimal profiling of 5% and minimal area of 0%. The automatically scored bands are checked manually against the gel strip images and the original gels to ensure that each band is correctly identified. For analysis, band comparison settings allow for a position tolerance of 1% over the full range of the gel and a minimal area of 0%. Cluster analysis is done with the Comparison/Clustering (bands) option using UPGMA clustering of the similarity matrix based on the Jaccard coefficient with optimization on.

IMTP Phase II

Country reports

Yellow Sigatoka

Results and discussion IMTP yellow Sigatoka Quindio, Colombia

Daniel Gerardo and Cayon Salinas,
CORPOICA, Av. Bolivar, Sector Rigivit No 28 Norte, AA 1807, Armenia, Quindio, Colombia

Local Cultivar: Dominico Harton

Environmental characteristics and particularities of design

The trial was planted in the experimental station "El Agrado" located in the corregimiento of Pueblo Tapao, municipio of Montenegro in the Department of Quindio. The experimental station is located in a plain at 1 320 m.a.s.l., it has an average temperature of 20°C and an average relative humidity of 70%. Rainfall is on average 2 100 mm/year. The experiment was rainfed. The soil is a sandy loam with a pH of 5.5 of the Andisol type. The experiment was planted on 19 March 1997 according to the IMTP protocols. Two local clones were also evaluated in the trial: FHIA-21 and AFRICA-1. Plant spacing was 3 x 2.5 m.

Agronomic traits

The analyses of variance showed highly significant differences among genotypes for all traits studied. On the other hand, they were all non significant for differences among blocks.

This trial went through several severe climatic events - a gale, a tornado and an earthquake, all of which severely affected the plants. For this reason the agronomic performance may not be as good as the average performance of bananas and plantains on this site.

Phenology and morphology

The local cultivar was the tallest of all at 346 cm. All the genotypes were shorter or equal to the local cultivar.

For the number of days from planting to shooting the local cultivar took 377 days. The only genotype that was significantly later than the local cultivar was Pisang Ceylan with 454 days.

For planting to harvest the local cultivar took 514 days on average, again Pisang Ceylan was later than the local cultivar at a significant level. Also later than the local were Pisang Berlin (593) and AFRICA-1 (606). None of the improved cultivars were significantly later than the local cultivar. Although FHIA-23 (563), SH-3436-9 (559) and FHIA-21 (581) have greater absolute mean values, the differences were not significant.

The local cultivar had an average bunch weight of 14.3 kg. The two improved cultivars that had significantly bigger bunches were SH-3436-9 with an average of 17.6 kg and FHIA-21 with an average of 21.9 kg. FHIA-21 was the genotype with the best yield for this location.

Response to disease

The usual susceptible reference clone, Pisang Berlin was not evaluated at harvest, therefore comparisons of means were carried out with clone Niyarma-Yik also known for its susceptibility.

At 6 months after planting, cultivars FHIA-23, SH-3436-9 and Pisang Berlin were no different from the susceptible landrace Niyarma-Yik. All other genotypes had lower infection indices than the susceptible genotype at a highly significant level.

When compared to the resistant Pisang Ceylan, all genotypes had significantly higher indices except the known highly resistant Yangambi Km 5, Calcutta 4 and P. Lilin.

At bunch emergence, susceptible and resistant clones could be clearly differentiated, those with an index lower than 14 that fall in the category of resistant or highly resistant and those with infection indices higher than 30 which can be classified as susceptible or highly susceptible.

The resistant group is formed by those that are not different from Pisang Ceylan, PV 03.44, PA 03.22 and FHIA-21; the highly resistant group is formed by those genotypes with no infection, Calcutta 4, Yangambi Km 5, P. Lilin and Saba.

On the susceptible group, we have the genotypes that are not different from Niyarma-Yik such as FHIA-23, SH-3436-9, P. Berlin, the local cultivar and AFRICA-1.

At harvest, there were still two groups that were well differentiated from each other. The genotypes that composed each group remained the same. Unfortunately, there were no infection index data from FHIA-23, P. Berlin and FHIA-21 at harvest.

Summary

Calcutta 4, Yangambi Km 5 and P. Lilin were highly resistant with hypersensitive response. PV 03.44, PA 03.22, P. Ceylan and Saba showed a resistant phenotype.

FHIA-21 showed a resistant phenotype until bunch emergence and since it was the best yielder it is possible to say that it was either resistant or tolerant to yellow Sigatoka. FHIA-23 and SH-3436-9 showed a tolerant phenotype.

Black Sigatoka

Results and discussion
IMTP black Sigatoka (2nd cycle)
Njombe, Cameroon

Catherine Abadie and Eric Fouré
CRBP, BP 832, Douala, Cameroon

Local cultivar: French Sombre

Environmental characteristics and particularities of design

The CRBP experimental station is located at a latitude of 4°35' N and 9°39' E. It is a plain of highly organic soils that have a pH of 6 and good soil drainage. The fields are rainfed and irrigated. The experiment was planted as specified in the protocol. Plant spacing was 3 m x 2.5 m. The clone Pisang Lilin was a dwarf somaclonal variant and therefore was not planted.

The highest temperature was 32.2°C and the lowest was 22.1°C with an average temperature of 27.1 °C. Rainfall was 2 086 mm/year. The highest relative humidity was 100% and the lowest was 32%, with an average of 72%. There were on average 161 days of rain and the number of hours with 90% humidity or more amounted to 303.

Agronomic traits

All the analyses of variance, plant height, days from planting to shooting, days from planting to harvest, follower's height, bunch weight, number of hands, fruit number and average fruit weight showed that there were highly significant differences among the genotypes. On the other hand, most analyses of variance were not significant for block differences. After the analyses of variance, all means were compared with the local cultivar mean.

Phenology and morphology traits

FHIA-23 was the tallest hybrid (352.3 cm) followed by PV 03.44 (326.7 cm), although these two hybrids did not show any significant differences from the local cultivar (337.4 cm). The same was true for the clones Saba (350.4 cm) and Pisang Ceylan (345.6 cm). All the other hybrids and landraces were similar to or shorter than the local cultivar.

Days from planting to shooting

The only hybrid that had a considerably longer vegetative cycle than the local cultivar was FHIA-23 (272 days). All the other hybrids and landraces had equal or shorter cycles than the local cultivar (216 days). The same was true for days from planting to harvest where FHIA-23 had a significantly longer cycle (370 days) than the local cultivar (292 days). All the other hybrids and landraces had equal or shorter cycles than the local cultivar.

Yield and production traits

FHIA-23 with almost 40 kg per bunch had the highest yield of all genotypes. It was followed by landraces Pisang Ceylan (34 kg), Saba (29 kg), somaclonal variant SH-3436-9 (26 kg) and landrace Yangambi Km 5 (21 kg). All these genotypes were significantly superior yielders compared to the local cultivar (16 kg). All the other hybrids and landraces produced bunches equal to or lighter than that of the local cultivar.

The higher yields of the clones mentioned above is related to the number of hands, fruit number and average fruit weight combined.

Response to disease

As the highly resistant reference clone was not planted, Pisang Ceylan was used as the resistant cultivar to make the comparisons of means. Already six months after planting, half of the genotypes began to show their resistance to Sigatoka. All of these clones – Calcutta 4, FHIA-23, SH-3436-9 and Yangambi Km 5 - had average infection indices of less than 10. When compared to Pisang Ceylan, they did not show any significant differences. When compared to the susceptible Pisang Berlin, they all had significantly lower indices.

At bunch emergence, the five most resistant clones continued to have significantly lower indices than the susceptible cultivar. When compared to Pisang Ceylan, the clones Calcutta 4 and Yangambi Km 5 did not show significant differences; while FHIA-23 and SH-3436-9 began to have significantly higher indices than the resistant reference, they kept the lowest infection indices among the hybrids.

At harvest, FHIA-23 was still significantly less infected than the susceptible clone and showed no differences in infection when compared to the resistant genotype.

Summary

FHIA-23 is considered to be highly resistant.

Results and discussion
IMTP black Sigatoka (1st cycle)
Guápiles, Costa Rica

Mauricio Guzman
CORBANA, Apdo 390-7210, Guápiles, Costa Rica

Local cultivar: Grande Naine

Environmental characteristics and particularities of design

The trial was planted in February 1996 at the experimental site of CORBANA, La Rita, Guápiles. The site was located at a latitude of 10°16' N, a longitude of 83°27' W and an altitude of 125 m.a.s.l. It was a plain of sandy loam with a soil pH of 6.03. The soil on the site was of the Andisols type with good drainage and a very slight slope. The trial was rainfed. Rainfall was 4 000 mm per year on average and the average temperature was 24°C. There were no special amendments to the evaluation protocol. Pisang Lilin was a dwarf somaclonal variant.

Agronomic traits

The analyses of variance showed that there were no highly significant differences among blocks for any of the traits studied. In contrast, there were highly significant differences among the genotypes.

Phenology and morphology traits

The local cultivar was 251 cm tall. All the hybrids in the experiment were taller than the local cultivar at a highly significant level except for PV 03.44 (237 cm). FHIA-23 was the tallest hybrid at 370 cm followed by PA 03.22 (339 cm) and SH-3436-9 (318 cm). Moreover, most of the landraces were taller than the local cultivar except for Calcutta 4 (224 cm), Pisang Berlin (251 cm) and Pisang Lilin, which was a weak dwarf variant.

The local cultivar shoot emerged 242 days after planting. FHIA-23 flowered much later at 319.8 days. Clone SH-3436-9 (281.4 days) was also significantly later than the local cultivar. Hybrids PV 03.44 and PA 03.22 were neither different nor earlier than the local cultivar (186.3 and 216.8 days respectively).

The local cultivar was harvested 331.6 days after planting. The hybrids followed the same pattern as for shooting, with FHIA-23 being the hybrid with the longest production cycle (409 days). SH-3436-9 was also later than the local cultivar at 375 days to harvest. Among the landraces, Yangambi Km 5 was the clone with the longest production cycle (467.6 days)

Yield and production traits

The local cultivar produced a bunch weighing 12 kg. FHIA-23 was the best yielding hybrid with a bunch of 38 kg, followed by SH-3436-9 which produced a 27 kg bunch. Hybrids PV 03.44 (8 kg) and PA 03.22 (9 kg) yielded less than the local cultivar.

The landraces that produced a better yield than the local cultivar were Saba and Pisang Ceylan. Yangambi Km 5, though with a higher yield than the local cultivar, was not statistically different from it. The other landraces and reference clones had very small yields.

For the number of hands, the local cultivar produced an average of 9. Again FHIA-23 outyielded all the hybrids with an average of 13 hands. SH-3436-9 was also more productive at a highly significant level with 11 hands. The other clones did not differ from the local cultivar or were inferior. FHIA-23 was more productive for fruit number and average fruit weight than the local cultivar and the other hybrids.

Response to disease

At six months after planting it was already possible to detect highly significant differences between the genotypes. FHIA-23 had a low infection index throughout the cycle. When the genotypes were compared to the susceptible reference clone Pisang Berlin, FHIA-23 showed a highly significant inferior infection index. Calcutta 4 evidently had the lowest infection index of all the genotypes tested and was regarded as the highly resistant reference accession. Saba also showed a significantly inferior infection index than Pisang Berlin, while Yangambi Km 5 showed a lower index than Pisang Berlin but no significantly different. Genotypes with equal or higher indices compared to the susceptible reference at 6 months after planting were SH-3436-9, Pisang Lilin, Niyarma-Yik and the local cultivar. All the genotypes were showed to have higher infection indices than the highly resistant reference Calcutta 4.

At bunch emergence, genotypes such as FHIA-23, PA 03.22, SH-3436-9, Yangambi Km 5, Saba, Pisang Ceylan and Calcutta 4 had significant inferior indices than the susceptible cultivar. Contrary to this, the local cultivar, Niyarma-Yik and PV 03.44 had infection indices similar to that of the susceptible reference.

At harvest there were highly significant differences among the genotypes. Though still lower than that of the susceptible reference clone, the infection index in FHIA-23 increased and was not statistically different to the susceptible cultivar. The same happened with Yangambi Km 5 and Pisang Ceylan. Only Calcutta 4 had highly significant inferior infection index compared to the susceptible cultivar. It is worth noting that FHIA-23, though not significantly different from the susceptible cultivar, was still the second least infected after Calcutta 4.

Results and discussion
IMTP black Sigatoka (2nd cycle)
Guápiles, Costa Rica

Mauricio Guzman
CORBANA, Apdo 390-7210, Guápiles, Costa Rica

Local cultivar: Grande Naine

Environmental characteristics and particularities of design

The trial was planted in February 1996 at the experimental site of CORBANA, La Rita, Guápiles. The site was located at a latitude of 10°16' N, a longitude of 83°27' W and an altitude of 125 m.a.s.l. It was a plain of sandy loam with a soil pH of 6.03. The soil on the site was of the Andisols type with good drainage and a very slight slope. The trial was rainfed. Rainfall was 4 000 mm/year on average and the average temperature was 24°C. There were no special amendments to the evaluation protocol. Pisang Lilin was a dwarf somaclonal variant.

Agronomic traits

Only the analysis of variance for the number of hands showed significant differences among blocks. In contrast, all the analyses of variance were highly significant for differences among the genotypes.

Phenology and morphology traits

The local cultivar was 291 cm tall. As in the plant crop, all the improved genotypes were taller than the local cultivar at a highly significant level, except for PV 03.44 (316 cm). In this generation, PA 03.22 was the tallest cultivar at 428 cm followed by FHIA-23 (407 cm) and SH-3436-9 (347 cm). Most landraces were also taller than the local cultivar at a highly significant level with the exception of Calcutta 4, Pisang Lilin and Pisang Berlin. No data was taken on days to flowering or days to harvest.

Yield and production traits

The local cultivar produced a bunch weighing 21 kg on average. FHIA-23 and SH-3436-9 produced larger bunches than the local cultivar at a highly significant level. FHIA-23 was the best yielding improved genotype at 37 kg followed by SH-3436-9 (34 kg). PV 03.44 (13 kg) and PA 03.22 (18 kg) did not differ from the local cultivar. Among the landraces, Pisang Ceylan was the best-yielding clone at 31 kg followed by Saba (31 kg). Both clones had a significantly superior yield than the local cultivar. The other landraces produced bunches of equal or lighter weight than the local cultivar.

For the number of hands per bunch, the local cultivar produced 10 hands, while FHIA-23 produced 15 and SH-3436-9 13. These two improved cultivars had a significantly greater number of hands than the local cultivar, while among the landraces, only Pisang Ceylan had a significantly greater number than the local. The same was true for the number of fruits. However, for the average weight of fruits, only SH-3436-9 at 140 g had highly superior values compared to the local cultivar and, among the landraces, only Saba (252 g) had values highly superior to those of the local cultivar.

Response to disease

The infection index data was taken at bunch emergence and at harvest only. At bunch emergence, the local cultivar had an index of 36.5, almost 10 points less than its own score in the first cycle, while at harvest it had the same infection index as in the first cycle.

The same pattern was true for FHIA-23, but with a much lower infection index: 21.7 at bunch emergence and 45.9 at harvest. In fact FHIA-23 had intermediate infection index patterns ranging between those for Pisang Ceylan and those for Yangambi Km 5.

Summary

FHIA-23 was resistant to black Sigatoka.

Results and discussion IMTP black Sigatoka San Pedro Sula, Honduras

Julio Coto and Phil Rowe
FHIA, Apdo Postal 2067, San Pedro Sula, Honduras

Local cultivar: FHIA-18

Environmental characteristics and particularities of design

The trial began in July 1996 in Centro Experimental y Demostrativo de Guarumas (CEDEG), FHIA, La Lima, Honduras. The experimental site was located at 31 m.a.s.l. The soil was of Andisol type with a pH of 7.8 and rainfall was 1 100 mm per year. The average temperature was 25°C and average relative humidity 80%.

The experimental design was a complete randomised block design with 5 blocks and included 12 genotypes. Each experimental unit had 5 plants.

The agronomic practices were those recommended by FHIA:

1. Manual weed control for the final 6 months and then a Paraquat-based herbicide;
2. Desuckering, by leaving only one sucker as follows: mother, daughter, granddaughter;
3. Deleafing was performed on those leaves showing 100% damage;
4. Fertilisation: 300 and 250 kg/ha/yr of nitrogen and potassium were applied respectively. No fungicides were applied. The trial was exclusively rainfed.

The clone Calcutta 4 was not evaluated due to adaptation and growth problems in the hardening phase. Pisang Lilin was a dwarf somaclonal variant. Only 15 plants of clone Niyarma-Yik were planted.

Agronomic traits

The analyses of variance for all traits showed that there were highly significant differences among the genotypes. There were no differences among blocks for plant height, bunch weight, number of hands, fruit number and average fruit weight. After the analysis of variance all means were compared with the local cultivar mean.

Yield and production traits

Although bunches of FHIA-23 (30 kg) and SH-3436-9 (26 kg) were heavier than those of FHIA-18, only FHIA-23 had a bunch weighing more than FHIA-18 (22 kg) at a highly significant level. This result was apparently due to the highly significant number of hands and fruit number of these two genotypes. The other clones produced as much as or less than the local cultivar.

Phenology and morphology traits

FHIA-23 at 373.64 cm was the tallest genotype at a highly significant level. The plant height of SH-3436-9, Saba, Pisang Ceylan and Niyarma-Yik was no different to that of the control cultivar (FHIA-18). PV 03.44, PA 03.22, Yangambi Km 5, Pisang Lilin and Pisang Berlin were as tall as or shorter than the local cultivar as shown by the Dunnet test.

The local cultivar flowered 359 days after planting. Hybrids that flowered at the same time as or earlier than the local cultivar were PA 03.22 (219 days) and PV 03.44 (254.7 days). In contrast, FHIA-23 (435 days) was later than the local cultivar at a highly significant level. SH-3436-9 (375 days) was not statistically different from the local cultivar. All the landraces flowered earlier than the local cultivar except for Niyarma-Yik. For days from planting to harvest, the genotypes followed a similar pattern. The local cultivar was harvested after 470 days. PA 03.22 (349 days) and PV 03.44 (387.8 days) were earlier than the local cultivar. FHIA-23 (512.4 days) did not differ significantly from the local cultivar, while SH-3436-9 was earlier (450 days) although not significantly so compared to the local cultivar.

All the landraces were harvested earlier than the local cultivar. Differences in the number of days from shooting to harvest are the cause of this change in rank.

Response to disease

No conclusive results can be drawn given that Calcutta 4, the highly resistant accession with a hypersensitive response, was not included and Pisang Lilin, the highly resistant cultivar with a partial resistance response, was a weak somaclonal variant. FHIA-23 had the highest infection index at all evaluation times.

Although no conclusive results can be drawn from the infection indexes obtained because of the lack of highly resistant and resistant reference clones, it is worth noting that FHIA-23 showed excellent tolerance to the fungus. This assessment was illustrated by the fact that it had the highest bunch weight despite its high infection index. The general tendency of the infection index shows a slight decrease at bunch emergence and a dramatic increase and separation of indexes between susceptible and resistant genotypes at harvest.

For the number of days from planting to shooting only FHIA-23 had a significantly longer production cycle than the control (a difference of 76.7 days). This character can be one factor influencing the infection index.

Progress report on multilocational évaluation of some *Musa* clones in Nigeria - June 1999

A. Tenkouano
Crop Improvement Division, IITA, Oyo Rd, PMB 5320, Ibadan, Nigeria

Background

The Plantain and Banana Improvement Programme of the International Institute of Tropical Agriculture routinely evaluates promising clones at several locations in order to assess their phenotypic stability for yield, plant phenology, and resistance to diseases. In 1995, seven genotypes[1] of the International *Musa* Testing Programme of INIBAP were included in a set of 36 genotypes for multilocational evaluation in Nigeria.

Experimental details

The genotypes were planted at three geographical locations following a north-south gradient in rainfall and soil fertility characteristics: Abuja (southern Guinea savannah), Ibadan (forest-savannah transition), and Onne (high rainfall humid forest). Site details are described in Table 1. The genotypes were grown under sole-cropping at all locations with an additional experiment under a multispecies alley-cropping system at Onne, giving a total of four environments. The experimental layout was a 6 x 6 simple lattice with 5 plants per plot, giving a total of 10 plants per genotype in each environment. Data were collected for two consecutive crop cycles on days to flowering (DTF, measured as time elapsed from shooting of mother plant to shooting of follower in the ratoon crop), days required for fruit filling (TFF, measured as number of days elapsed from shoot to harvest), plant height (PHT, cm), height of tallest sucker at harvest (HTS, cm), youngest leaf with necrotic spots at flowering (YLSf), bunch weight (BWT, kg), number of hands (HND), number of fruits (FNB), fruit length (FTL, cm) and circumference (FCR, cm). Both location-specific and combined analyses of variance were performed on plot means, using the GLM procedure of SAS.

Results highlights

ANOVA details are given in Table 2. Significant differences between the genotypes were expressed for all traits. Similarly, significant differences between locations were found for all traits, except the number of days to flowering. In contrast, differences between crop cycles were only significant for bunch weight. There was a significant interaction effect between locations and crop cycles for all traits, except fruit length and fruit circumference. Location x clone interaction was significant for the number of days to flowering, plant height at flowering, the height of the tallest sucker, bunch weight, and average fruit length. There was no significant interaction between clones and crop cycles, except for the youngest leaf spotted at flowering and the number of fruits per plant.

The genotypes FHIA-23, Pisang Ceylan, SH-3436-9 and Saba were among the top-yielding accessions at all four locations in both crop cycles, while the EMBRAPA materials had the lowest yields, regardless of location and crop cycle (Table 3). The high yield of FHIA-23 was associated with a large number of fruits. The Brazilian accessions were earlier to flower than most other accessions at all locations both in the plant crop and the ratoon crop cycles (Table 4). Except for Pisang Ceylan and Saba, other IMTP accessions were of relatively medium stature. Sucker growth was rather vigorous for all IMTP accessions, particularly EMB402, Yangambi Km 5, Pisang Ceylan, and Saba.

All IMTP accessions expressed higher resistance to black Sigatoka than the plantain control, particularly at Onne where inoculum pressure and relative humidity are highest.

1 'EMB402', 'EMB403', 'FHIA-23', 'Yangambi Km 5', 'Pisang Ceylan', 'SH-3436-9', and 'Saba'

Table 1. Some biophysical characteristics of test locations in Nigeria.

Characteristics	Abuja	Ibadan	Onne
Geographical location	9°16'N; 7°20'E	7°31'N; 3°54'E	4°51'N; 7°03'E
Altitude (masl)	300	150	10
Annual rainfall (mm)	1303	1300	2400
Temperature (°C)	26 - 34	26.5	27
Radiation (MJ m^{-2} $year^{-1}$)	5846	5285	5060
Soil type	Ferris luvisol	Alfisol, slightly acidic	Ultisol, highly acidic

Table 2. Mean squares and tests of significance.

Source of variation	Mean squares				
Yield and yield components	**BWT**	**HND**	**FNB**	**FTL**	**FCR**
Locations	1522.7 **	120.3 **	47021.6 **	158.4 *	163.6 **
Replications (locations)	62.3 **	3.4 **	2692.9 **	19.4	4.2
Clones	147.1 **	25.7 **	9571.4 **	71.6 **	26.4 **
Locations x clones	34.9 **	1.7	936.0	21.5 **	6.3
Clones x replications (locations)	22.3 **	1.7 **	830.5 **	7.9	4.9
Crops	1031.4 *	59.3	38787.0	78.1	32.9
Locations x crops	47.3 *	15.3 **	10207.9 **	16.1	3.4
Clones x crops	12.5	0.8	858.9 *	4.6	3.7
Locations x clones x crops	15.9	1.0	539.8 *	6.5	5.3
Error	12.0	1.0	335.5	30.6	7.8
R-Square	0.94	0.95	0.97	0.78	0.85
Phenology and disease resistance	**DTF**	**TFF**	**PHT**	**HTS**	**YLSf**
Locations	241835.1	17460.0 **	229166.7 **	295566.6 **	318.5 **
Replications (locations)	194751.0 **	654.6	10333.0 **	16619.7 **	86.4 **
Clones	47101.5 **	4496.0 **	25618.5 **	53141.0 **	107.9 **
Locations x clones	13227.9 **	814.3	1430.9 **	4124.8 **	85.9
Clones x replications (locations)	5163.5 **	731.6	699.9 *	1947.1 **	87.2 **
Crops	1945937.4	1078.0	222746.7	351.7	13.3
Locations x crops	2312354.9 **	2727.3 *	47450.5 **	9218.3 *	28.5 **
Clones x crops	4350.2	851.2	1310.9	1626.3	3.3 *
Locations x clones x crops	4530.5 **	694.9	999.5 **	2344.3 **	2.0
Error	1926.4	555.9	274.5	1259.9	1.6
R-Square	0.99	0.89	0.99	0.96	0.99

*,**: indicate significant F-test at the 0.05 and 0.01 probability levels, respectively.

BWT: bunch weight
DTF: days to flowering
FCR: circumference
FNB: number of fruits
FTL: fruit length
HND: number of hands
HTS: height of tallest sucker at harvest
TFF: days required for fruit filling
YLSf: youngest leaf with necrotic spots at flowering

Table 3. Performance of IMTP clones in multilocational trials in Nigeria - Yield data.

Locations	Clones	Plant crop					Ratoon crop				
		BWT	HND	FNB	FLT	FCR	BWT	HND	FNB	FLT	FCR
ABJ	EMB402	7.3	6.0	75.5	12.5	12.5	3.7	4.5	49.5	12.5	10.5
	EMB403	6.5	5.5	79.5	12.0	12.5	4.2	6.5	71.5	26.5	9.5
	FHIA-23	23.0	12.0	181.5	14.5	12.5	13.9	8.5	117.0	16.5	11.0
	Yang. Km 5	6.9	6.5	106.5	9.0	11.5	3.7	5.5	78.5	11.0	9.0
	P. Ceylan	18.2	11.0	175.5	13.5	13.5	6.4	9.0	117.5	11.5	10.0
	Saba	17.1	7.0	96.0	16.5	16.5	10.3	5.5	67.0	19.0	15.0
	SH-3436-9	26.3	10.0	164.5	17.0	14.0	37.1	12.5	129.0	19.0	14.0
	Agbagba (control)		10.1	7.0	63.5	17.0	13.0	7.1	6.0	34.5	24.5
14.0											
	Valery (control)	8.8	7.5	88.0	12.5	11.5	8.3	7.0	91.0	16.0	11.0
	Trial mean	13.8	7.4	99.6	15.1	13.6	17.1	7.7	106.2	15.0	14.6
	LSD0.05	4.4	0.9	17.6	2.9	1.5	5.4	1.4	38.8	1.9	6.7
	CV (%)	23.5	8.5	12.8	14.1	7.9	22.9	13.3	26.4	9.5	33.0
IBD	EMB402	5.0	6.0	81.0	13.5	11.0	9.9	7.0	101.5	12.0	12.0
	EMB403	6.7	7.0	84.0	13.5	11.0	7.8	7.5	100.5	10.0	11.5
	FHIA-23	13.9	9.0	135.0	17.0	13.5	24.8	10.0	150.0	16.5	14.0
	Yang. Km 5	3.4	6.5	110.0	11.0	9.0	12.9	7.5	134.0	11.0	12.0
	P. Ceylan	6.4	10.0	144.0	10.5	8.5	18.0	14.0	176.0	11.0	10.0
	Saba	15.3	7.5	97.0	17.0	13.0	27.0	8.0	209.5	16.0	18.0
	SH-3436-9	8.6	7.5	92.5	16.5	11.0	11.4	8.0	1.0	18.0	12.5
	Agbagba (control)		4.5	5.0	24.0	20.0	14.0	14.5	5.0	58.0	19.0
15.0											
	Valery (control)	5.0	7.0	83.0	14.0	10.0	10.4	7.5	110.0	14.0	11.5
	Trial mean	9.0	6.7	83.0	17.1	12.1	10.1	6.4	77.8	18.7	12.2
	LSD0.05	5.5	1.4	24.1	9.6	5.1	8.0	1.0	23.3	9.1	2.1
	CV (%)	44.6	15.0	21.0	40.7	30.8	58.0	11.0	21.6	35.3	12.1
OAC	EMB402	5.2	6.5	87.5	10.0	8.5	14.0	7.5	124.0	15.5	12.0
	EMB403	10.1	8.0	114.0	13.5	9.5	11.4	8.5	121.0	14.0	11.0
	FHIA-23	21.9	10.5	171.0	17.5	12.5	24.0	12.0	216.5	15.5	12.5
	Yang. Km 5	6.7	7.5	105.0	11.5	10.0	11.7	7.5	129.5	14.0	10.5
	P. Ceylan	9.1	10.0	156.5	11.5	10.5	16.8	14.0	230.5	11.0	11.0
	Saba	9.1	7.0	40.5	19.5	12.5	8.5	7.5	20.0	.	.
	SH-3436-9	15.9	9.5	127.5	18.0	11.5	21.9	12.0	1.9	18.5	12.5
	Agbagba (control)		9.8	6.0	41.5	22.5	15.5	9.5	7.0	58.0	18.5
15.0											
	Valery (control)	9.4	8.5	127.0	15.5	9.5	13.6	9.0	128.0	16.0	10.0
	Trial mean	10.4	7.6	101.3	14.9	11.0	15.1	9.2	144.8	16.0	11.8
	LSD0.05	5.5	1.9	35.2	4.7	2.4	8.0	2.6	63.2	3.7	2.1
	CV (%)	38.9	18.1	25.1	22.5	15.1	38.7	20.5	31.5	16.9	12.8
OMC	EMB402	1.9	5.0	57.5	8.5	7.5	5.1	6.0	84.5	11.5	9.5
	EMB403	1.6	5.5	57.0	7.5	7.0	4.7	6.5	84.0	10.0	8.0
	FHIA-23	8.8	8.0	109.5	14.0	10.0	12.2	7.5	10.0	.	.
	Yang. Km 5	2.9	5.0	64.5	9.5	8.5	10.0	8.0	125.0	13.0	11.0
	P. Ceylan	9.1	9.0	138.5	10.5	10.5	8.4	10.0	.	.	.
	Saba	4.9	5.0	66.5	13.0	12.0	6.0	8.0	123.0	.	.
	SH-3436-9	6.6	7.0	84.5	13.5	10.5	8.8	8.0	1.1	17.0	0.1
	Agbagba (control)		5.2	6.5	24.0	19.5	13.5	5.8	7.0	24.0	. .
	Valery (control)	5.9	7.0	79.5	14.5	9.5	.	5.5	44.5	.	.
	Trial mean	6.3	5.9	68.5	14.0	10.9	8.6	6.7	87.1	14.6	11.1
	LSD0.05	2.4	1.1	14.6	1.7	1.1	4.7	1.9	26.7	6.2	4.4
	CV (%)	26.2	12.9	15.4	8.5	7.1	39.8	20.2	22.2	31.2	29.1

ABJ: Abuja IBD: Ibadan OAC: Onne Alley Crop OMC: Onne Mono Crop

Table 4. Performance of IMTP clones in multilocational trials in Nigeria - Phenological and disease response data.

Locations	Clones	Plant crop					Ratoon crop				
		DTF	TFF	PHT	HTS	YLSf	DTF	TFF	PHT	HTS	YLSf
ABJ	EMB402	281.5	184.0	267.5	410.5	8.2	312.0	148.0	249.5	281.0	8.6
	EMB403	300.0	177.0	196.0	287.0	7.0	281.5	150.5	197.5	209.0	8.5
	FHIA-23	492.0	113.0	306.0	172.5	7.8	494.0	112.0	301.5	211.5	8.3
	Yang. Km 5	523.0	140.0	317.0	339.0	7.7	388.5	163.5	245.5	201.0	8.0
	P. Ceylan	372.5	151.5	349.0	394.5	11.8	523.0	44.5	286.5	280.0	10.3
	Saba	347.5	152.5	344.5	424.0	12.5	326.0	71.5	259.5	250.5	8.7
	SH-3436-9	410.0	137.0	274.5	199.0	10.2	745.5	128.5	332.0	230.5	8.5
	Agbagba (control)	454.0	101.0	341.0	142.5	6.2	477.5	85.0	282.0	115.0	10.0
	Valery (control)	541.0	122.0	200.0	210.5	5.9	457.0	99.0	233.0	123.0	8.9
	Trial mean	403.8	139.6	296.0	261.3	8.8	693.4	132.4	354.3	258.0	11.7
	LSD0.05	60.4	14.6	32.2	61.0	1.7	83.8	39.1	42.3	66.8	32.4
	CV (%)	10.8	7.5	7.8	16.8	13.4	8.7	21.3	8.6	18.7	19.9
IBD	EMB402	376.5	141.0	310.5	250.0	7.6	502.0	160.5	413.5	308.0	7.4
	EMB403	439.5	154.0	248.0	205.0	6.6	495.5	172.5	302.5	219.0	7.5
	FHIA-23	398.0	119.0	317.5	202.5	6.8	777.0	202.0	320.0	204.0	10.0
	Yang. Km 5	341.5	92.5	262.5	223.5	7.1	740.0	120.5	364.5	303.0	.
	P. Ceylan	479.0	150.5	302.5	198.0	8.6	589.0	135.0	430.0	270.0	10.5
	Saba	484.5	68.5	332.0	190.5	8.3	572.0	108.5	458.0	257.5	10.8
	SH-3436-9	350.0	102.5	245.5	123.0	7.4	510.5	101.0	254.0	153.5	8.6
	Agbagba (control)	365.0	92.0	270.0	190.0	7.3	717.0	111.0	330.0	260.0	7.5
	Valery (control)	367.0	104.0	209.0	149.0	7.0	745.5	140.5	236.0	193.0	5.1
	Trial mean	407.7	113.3	297.2	189.0	8.2	674.5	116.7	275.3	204.2	9.1
	LSD0.05	119.1	57.5	39.4	66.9	1.7	122.0	36.0	30.6	61.7	2.4
	CV (%)	21.1	36.6	9.6	25.6	15.1	13.0	22.2	8.0	21.8	18.8
OAC	EMB402	238.5	119.0	308.5	330.0	9.6	495.5	124.0	471.5	410.5	9.4
	EMB403	252.0	142.5	226.5	226.0	8.9	473.5	184.5	313.0	206.0	7.8
	FHIA-23	435.5	103.5	356.0	286.0	5.9	753.5	100.5	382.0	279.5	5.8
	Yang. Km 5	302.5	119.0	261.0	397.0	6.6	446.5	226.5	422.5	370.5	7.4
	P. Ceylan	397.0	102.5	410.0	421.5	6.2	547.5	99.0	461.5	402.0	6.4
	Saba	426.0	124.5	402.0	360.5	6.8	674.5	118.5	462.5	337.5	7.2
	SH-3436-9	357.5	107.0	295.5	266.0	7.2	636.5	103.5	342.5	227.0	6.4
	Agbagba (control)	469.5	81.0	397.5	241.5	5.3	671.0	81.0	399.0	140.0	5.3
	Valery (control)	323.5	97.0	229.0	194.0	7.4	569.0	133.5	273.5	143.5	6.2
	Trial mean	342.6	110.0	328.0	298.7	8.2	576.1	117.6	406.8	280.1	7.0
	LSD0.05	58.1	15.9	23.6	52.1	1.8	55.6	55.7	29.7	50.9	1.5
	CV (%)	12.2	10.5	52.0	12.6	15.3	7.3	34.2	5.3	13.1	15.0
OMC	EMB402	272.5	114.0	213.5	225.5	9.4	515.0	114.0	330.5	211.5	7.4
	EMB403	259.0	112.0	144.5	149.0	10.0	487.5	103.5	206.5	149.5	6.6
	FHIA-23	501.0	109.0	262.5	208.0	4.7	808.0	91.0	294.0	197.5	5.1
	Yang. Km 5	302.0	140.0	178.5	269.5	9.2	440.5	123.0	279.0	231.5	6.6
	P. Ceylan	361.5	103.0	293.5	248.0	7.3	608.0	101.5	307.0	233.0	6.4
	Saba	487.0	132.0	274.5	194.5	3.5	776.0	58.5	350.0	189.0	6.5
	SH-3436-9	411.5	107.5	195.0	181.5	5.4	669.5	108.0	225.5	174.5	4.7
	Agbagba (control)	517.0	86.0	276.0	116.5	5.6	793.0	60.0	321.0	158.0	5.5
	Valery (control)	343.0	99.0	197.5	167.5	5.6	576.5	90.5	218.5	126.5	6.1
	Trial mean	384.3	111.2	247.0	186.7	7.6	674.8	100.0	300.5	191.8	6.1
	LSD0.05	68.3	17.5	25.5	42.7	2.4	88.0	21.6	24.0	46.2	1.2
	CV (%)	12.8	11.3	7.5	16.5	21.8	9.5	15.7	5.7	17.3	13.9

ABJ: Abuja IBD: Ibadan OAC: Onne Alley Crop OMC: Onne Mono Crop

Results and discussion IMTP Sigatoka Bago Oshiro, Philippines

Lydia Magnaye, Lorna Herradura and Marilyn Alforque
BPI, Bago Oshiro, Davao City 8000, Philippines

Local cultivar: Lakatan

Environmental characteristics and particularities of design

The trial was planted on 20 June 1996 at the experimental station of the BPI in Bago Oshiro, Davao City, Mindanao. The experimental site was located at a latitude of 7°5'N and a longitude of 125°36' E. It had an elevation of 100 m.a.s.l. The topography of the site corresponds to a plain with a clay loam soil texture. The soil pH is 5.4 and belongs to the Ultisols type. Soil drainage was moderate and irrigation was available. Climatic conditions were favourable for disease development. Rainfall was evenly distributed throughout the year with an average temperature of 26°C and relative humidity of 83 to 86%. The trial was conducted following the standard protocol.

Agronomic traits

As expected all the analyses of variance were highly significant among genotypes for all the traits studied. The experiment was quite uniform with no statistical differences among the blocks.

Phenology and morphology traits

The local cultivar Lakatan had an average height of 207 cm. Although FHIA-23 (246 cm) and PV 03.44 (242 cm) were taller, none of them were significantly taller. The other two hybrids, SH-3436-9 and PA 03.22 had lower averages at 182 cm and 174 cm respectively. The tallest clone of the trial was Saba (295 cm). It was also the only one with a highly significant higher value. Pisang Lilin was a dwarf somaclonal variant at 107 cm.

The number of days from planting to shooting and the number of days from planting to harvest followed a very similar pattern. The local cultivar flowered 395 days after planting and was harvested 454 days after planting. Most hybrids were earlier in absolute terms than the local cultivar both for shooting and harvest. FHIA-23 did not show any statistical differences compared to the local cultivar for either of these two traits. SH-3436-9 was earlier for shooting (378 days) and for harvesting (432 days). But since the Dunnett analysis is a one-sided test, it was not possible to demonstrate if these differences were significant.

Yield and production

In this experiment overall yields were low. Lakatan, the local cultivar, produced 10.4 kg on average. Among the hybrids, SH-3436-9 (10.4 kg) and PV 03.44 (9.75 kg) did not show any significant differences when compared to the local cultivar. FHIA-23 had a highly significant superior yield (15.8 kg) than the local cultivar. PA 03.22 produced a 5.5 kg bunch on average.

Among the landraces, as expected, Saba (20.5 kg) had a significantly superior yield than the local cultivar. Although Pisang Ceylan had a higher average, the difference compared to Lakatan was not significant.

None of the hybrids had a significantly higher number of hands or a significantly higher fruit number than the local cultivar. On the contrary, the average fruit weight of FHIA-23 was significantly superior (111.4 g) to that of the local cultivar (73 g). The landrace Saba was superior for all production traits when compared to the local cultivar.

Response to disease

The analyses of variance performed for each of the three evaluation times were highly significant for differences among genotypes but not for differences among the blocks.

At 6 months after planting, Pisang Berlin, the susceptible cultivar, showed an infection index of 34; only Niyarma-Yik and Lakatan had higher indices at a highly significant level. Pisang Lilin was no different from the susceptible reference clone as it was a weak somaclonal variant. SH-3436-9 was no different from the susceptible cultivar. All the other genotypes had highly significant lower indices 6 months after planting.

When compared to the resistant reference Calcutta 4, most hybrids had higher indices, except for PV 03.44, which did not differ at a significant level. As for the landraces, the only one that did not differ from Calcutta 4 was Saba. All the others had higher indices than Calcutta 4 at a significant level.

At bunch emergence, the general tendency was an increase in the index. However, PV 03.44 still had a lower index than the susceptible reference. All the other hybrids, though with lower indices than the susceptible clone, did not differ at a significant level. As for the landraces, Yangambi Km 5, Saba and Calcutta 4 had highly significant inferior indices than the susceptible reference clone. Niyarma-Yik and the local clone did not differ from the susceptible clone.

When compared to the resistant reference clone, the only hybrid that had a higher index at a significant level was SH-3436-9. The other hybrids, although with higher indices, did not differ significantly. These are very strange results as Calcutta 4 should not have shown any infection.

The landraces, Yangambi Km 5, Pisang Ceylan and Saba did not differ from Calcutta 4, while Pisang Berlin, Niyarma-Yik and the local cultivar had highly significant higher indices.

At harvest, the index increased dramatically from an average of 30.7 at bunch emergence to a general average of 45.9. FHIA-23, PV 03.44, PA 03.22 and SH-3436-9 did not differ from the susceptible reference. Niyarma-Yik and the local cultivar had very high infection indices that were higher than that of the susceptible cultivar at a highly significant level.

When compared to the resistant reference clone, FHIA-23, PV 03.44, PA 03.22 and SH-3436-9 did not differ at a significant level from Calcutta 4 although they had higher values. This apparent contradiction with the last paragraph is explained by the high coefficient of variability for this character. The susceptible clones Niyarma-Yik and the local cultivar had higher indices than the resistant reference clone at a highly significant level.

The hybrids FHIA-23, PV 03.44, PA 03.22 and SH-3436-9 had very long disease development times that account for their tolerance to the disease.

Summary

FHIA-23 and PV 03.44 were resistant to Sigatoka, while Niyarma-Yik and Lakatan were highly susceptible.

Results and discussion
IMTP Black Sigatoka
Tongatapu, Tonga

Paelata Vi Nai[1] and Ron Peterson[2]
[1]MAFF, PO Box 14, Nuku'Alofa, Tonga
[2]QDPI, PO Box 1054, Mareeba, QLD 4880, Australia

Local cultivar: Williams

Environmental characteristics and particularities of design

Vaine Research Station (Ministry of Agriculture and Fisheries) is located in Tongatapu, Kingdom of Tonga at a latitude of between 15° and 23.5° S and a longitude of between 173° and 177° W. Rainfall was 1 775.5 mm per year. Minimum temperatures were around 18°C in winter (from May to September), while maximum temperatures were around 32°C in summer (from October to April).

Twelve hybrids or cultivars were planted in a randomised block design with five replicates and five plants per plots. The distance between rows, and plants within rows, was 3 m and 2.5 m respectively. A row of the susceptible variety Williams was planted after each second row of testing plants to ensure an even level of inoculum throughout the trial area.

The establishment rate was 95 to 100% in all lines except for Pisang Lilin and Niyarma-Yik. Survival in these two lines was only 50 to 60% after one week, and zero for Pisang Lilin after four weeks. The trial area was planted on 9 January (six months after deflasking) when the plantlets were 30 to 40 cm tall. Twenty-five plantlets of each cultivar or hybrid were planted (five plants in five plots), except for Niyarma-Yik, which had only 20 plants available (five plants in four replicates). Replacement Pisang Lilin plantlets from the Maroochy Tissue Culture Laboratory were planted on 5 June 1996, six months after the main planting had been done. The late planting prevented these plants from being used in any disease or agronomic evaluation.

Plant survival after planting was a problem, due mainly to the Banana Bunchy Top Virus and Cucumber Mosaic Virus. Plants infected with these viruses were removed when symptoms became evident. A number of plants were also damaged by cattle on one occasion, while a few other plants were knocked over during a mild storm in early March. The number of plants available for assessment varied with each assessment (Table 1). Pisang Lilin plants planted 6 months after the main planting period were not assessed.

Cyclone Hina destroyed the entire trial on 16 March 1997. Fortunately more than 90% of the bunches had been harvested and every effort was made to salvage as much of the remaining fruit as possible. Most of the bunches salvaged were from the late maturing lines.

Weather conditions

Weather data was available for only 10 months in 1996. Monthly rainfall ranged from 31.7 mm in July to 522.4 mm in January. Total rainfall was above average (1 775.5 mm) with 1 734.6 mm for only 10 months. Data were not available for the normally wet months of February (January 552.4 mm and March 300.9 mm) and December (November 88.5 mm and previous January 552.4 mm). The number of wet days ranged from 17 in January to 5 in July.

Conditions from January to June favoured the development of black Sigatoka. Rain was recorded over at least 12 days during this period and temperatures were above 25°C during the day and above 18°C at night. Relative humidity was also high (>82%) (Figure 4).

Results

The number of plants assessed for each character is listed in Table 1.

Disease development

Black Sigatoka development was relatively severe throughout the trial area. The DDT for the highly susceptible variety Niyarma-Yik was only 45 days and more than 50% of the surface of all leaves present on most Williams plants at harvest showed disease symptoms.

Disease Incubation Time (DIT) (Table 2)

DIT data were recorded for all cultivars indicating that all genotypes were infested and that disease was generalised across the trial area.

DIT for the seven “test” (unknown) hybrids or cultivars was very similar to the DIT for Pisang Berlin (30 days) which has a resistant reaction to black Sigatoka. The DIT for the extremely resistant accession, Calcutta IR 124, was 65 days and for the highly susceptible cultivar Niyarma-Yik, 24 days. Williams had a DIT of 25 days.

These data indicate that DIT is not a suitable parameter to differentiate between genotypes with different levels of resistance. Moreover, it is difficult and time-consuming to assess DIT, as it requires that the first streak stage of the disease be recognised and located on the marked leaves.

Disease Evolution Time (DET) (Table 2)

Mature black Sigatoka lesions did not develop on the reference accession Calcutta IR 124 confirming that it has an extremely resistant response to the strains of the black Sigatoka organism encountered at this trial site. The DET for the resistant cultivar Pisang Berlin was 44 days and 22 days for the highly susceptible cultivar Niyarma-Yik and 25 days for Williams.

A lesion development reaction (mature fully developed lesions) was recorded for all “test” genotypes. The DET data separated the “test” varieties into two groups. Five hybrids or cultivars had a DET value (71-94 days) much greater than the resistant Pisang Berlin with 44 days. This DET data ranked these five hybrids or cultivars as highly resistant. Two test hybrids, PV 03.44 and PA 03.22, had DET values in the same range as Williams and Niyarma-Yik (highly susceptible). DET, as it relies on the DIT data, is also difficult and time-consuming to acquire.

Disease Development Time (DDT) (Table 2)

DDT, which is the total time for the disease symptoms to develop, resulted in a similar separation of cultivars or hybrids to the DET data. Five hybrids or cultivars were ranked as highly resistant with a DDT value of 101 to 136 days while the two hybrids, PV 03.44 and PA 03.22, were ranked as susceptible. The DDT for these two hybrids (62 to 63 days) were about midway between those of the resistant cultivar Pisang Berlin (76 days) and the highly susceptible cultivar Niyarma-Yik (45 days). The DDT for Williams was 53 days.

DDT is easier and faster to assess than DIT. It also provided a greater range of results and if additional reference varieties had been included (highly resistant and susceptible), the DDT may have allowed a greater differentiation of the hybrids/varieties.

Youngest Leaf Spotted (YLS) (non bunched plants) (Table 2)

The YLS data of 5, for the highly susceptible cultivar Niyarma-Yik, and 8 for the resistant cultivar Pisang Berlin enable the “test” hybrids or cultivars to be separated into three groups. The hybrids, PV 03.44 and PA 03.22, with YLS values of 7, were ranked as susceptible, the cultivars Saba (YLS 9) and Pisang Ceylan (YLS 10) as resistant, while the other three, Yangambi Km 5, FHIA-23 and SH-3436-9 with YLS values of 11 as highly resistant.

YLS data collection was relatively rapid and easy to assess and enabled a further separation of the hybrids or cultivars compared to the DDT data.

Leaf Emergence Rate (LER) Table 2

The LER data recorded were over a relatively narrow range of 0.82 to 1.03 leaves per week over the pre-bunch period. Pisang Ceylan with a LER value of 0.82 had the slowest growth rate while Yangambi Km 5 with a LER value of 1.06 had the fastest growth rate.

Youngest Leaf Spotted (YLS) (bunched plants) (Table 3)

YLS on bunched plants is a means of identifying genotypes that tend to be less resistant as the leaves mature. The YLS at bunching for the reference highly susceptible variety, Niyarma-Yik was 6.7 and for the resistant Pisang Berlin, 7.2. These data rated PV 03.44 (6.8) and PA 03.22 (6.6) as highly susceptible, Saba (9.3) as resistant, and Pisang Ceylan (11.0), Yangambi Km 5 (12.2), SH-3436-9 (13.3) and SH-3444 (14.7) as highly resistant.

Midway between bunch emergence and harvest, the YLS (mid bunch) decreased for all hybrids or cultivars. In the highly susceptible Niyarma-Yik, the YLS decreased from 6.7 to 5.2, while in the resistant cultivar, Pisang Berlin, it decreased from 9.2 to 8.1. Similar decreases were recorded in the “test” hybrids or cultivars, except in Pisang Ceylan where the drop was greater (11.0 to 9.6) and resulted in changing the category for this cultivar from highly resistant to resistant.

At harvest, YLS values had further decreased across all hybrids or cultivars and in Saba the decrease was considerable (7.3 to 4.4) resulting in a change in category for this cultivar from resistant to susceptible. All other hybrids or cultivars had responses similar to those at mid-harvest. PV 03.44, PA 03.22 and Williams had lower YLS values (<1) than the highly susceptible cultivar Niyarma-Yik (3.8).

Disease Severity Index (DSI) (Table 4)

The DSI values at 6 months for the seven “test” hybrids or cultivars were all relatively similar (14.8 - 21.7) and close to the resistant response recorded for Pisang Berlin (18.1). No differentiation between hybrids or cultivars was possible. The highly susceptible response of Niyarma-Yik was 34.4 and the extremely resistant response of Calcutta IR 124 was 2.5. The DSI for Williams (31.2) was a highly susceptible response.

At bunching the DSI values covered a greater range and differentiation was possible. The DSI for PV 03.44 (29.9), PA 03.22 (34.8) and Williams (30.0) were similar to the highly susceptible response of Niyarma-Yik (29.5). Saba (21.5), Yangambi Km 5 (20.0) and Pisang Ceylan (19.0) recorded responses similar to the resistant Pisang Berlin (22.7). DSI for SH-3436-9(13.5) and FHIA-23 (8.6) were much lower and were ranked as being highly resistant responses. DSI for Calcutta IR 124 (extremely resistant) was 1.8.

At harvest there was a wide range of DSI values recorded for cultivars with a lesion development reaction, i.e., from 12.1 to 98.2. Calcutta IR 124 which has an extremely resistant reaction (no mature lesions) had a DSI of <1. The hybrids PV 03.44 and PA 03.22 had DSI values of 81.5 and 98.4 respectively, which were far higher than the highly susceptible response of 39.0 for Niyarma-Yik. Most of the remaining leaves on these two hybrids were highly diseased with >33% of the leaf (grades 5 or 6) showing symptoms of black Sigatoka. Williams had a similar DSI (97.2) to PV 03.44 and PA 03.22.

Saba recorded a highly susceptible response with a DSI of 35.1, while Pisang Ceylan (22.0) had a resistant response. Yangambi Km 5 (17.4), SH-3436-9(18.3) and FHIA-23 (12.1) had responses rated as highly resistant. DSI at or near harvest is an effective parameter for differentiating hybrids or cultivars based on levels of resistance to black Sigatoka.

Overall ratings (Tables 5 and 6)

The response of the seven “test” hybrids or cultivars based on the reaction of the reference varieties varied with the character used in the assessment (Table 5). DIT and DSI (6 months) data did not allow any differentiation between the hybrids or cultivars. The DET and DDT data for the two hybrids PV 03.44 and PA 03.22 identified these hybrids as highly susceptible to black Sigatoka. The other 5 hybrids or cultivars gave highly resistant responses to these parameters.

In the four YLS assessments, Saba gave 3 resistant responses and 1 susceptible response, while Pisang Ceylan gave 3 resistant responses and 1 highly resistant response. The two hybrids SH-3436-9 and FHIA-23 and the cultivar Yangambi Km 5 all had highly resistant responses to these parameters.

Saba had a resistant response to the DSI (bunch) assessment and a highly susceptible response to the DSI (harvest) assessment. Pisang Ceylan and Yangambi Km 5 had resistant responses to both these DSI assessments while SH-3436-9 and FHIA-23 both gave highly resistant responses to these assessments.

An examination of all responses from the 10 characters assessed allowed an overall ranking to be applied to each test hybrid or cultivar (Table 6). The FHIA hybrid FHIA-23 and the Cuban selection from a FHIA hybrid, SH-3436-9, were rated as highly resistant with 7 and 8 highly resistant responses respectively, plus two resistant responses. The cultivar Yangambi Km 5 with 7 highly resistant and 3 resistant responses were also rated as highly resistant. Saba with 6 resistant responses and Pisang Ceylan with 7 were rated as resistant while the two hybrids from Brazil were rated as highly susceptible with 7 highly susceptible responses. Williams gave responses equivalent to the highly susceptible Niyarma-Yik except just before harvest when disease levels were far more severe.

Agronomic features (Table 7)

The accession Calcutta IR 124 bunched very rapidly (211 days) and before any other hybrid or cultivar, though the bunches failed to develop and mature. Time to bunch for the other hybrids and cultivars varied considerably with the two hybrids from Brazil being the earliest at 239 and 256 days, while the FHIA hybrid, FHIA-23, and the Cuban selection from a FHIA hybrid, SH-3436-9, were the slowest to bunch (378 and 345 days respectively).

Days to harvest also varied broadly from 357 for Pisang Berlin to 432 for FHIA-23, and there was an even wider range with the time from bunching to harvest. The cyclone and the salvaging of bunches (bunches not mature) together with the level of black Sigatoka contributed to the large differences between hybrids or cultivars.

FHIA-23 produced the largest bunches (36.5 kg) followed by SH-3436-9 (28.8 kg), Williams (22.8 kg) and Pisang Ceylan (20.3 kg). The other hybrids or cultivars produced bunches ranging from 5.3 kg for Pisang Berlin to 17.1 kg for Saba. The two highly susceptible hybrids from Brazil had relatively small bunches of 9.3 kg and 11.3 kg. Saba produced relatively small bunches (17.1 kg) with a few (67) large fruits (231.1 g). Fruit weight for the other hybrids or cultivars ranged from 49.0 g for Pisang Berlin to 150.3 g for SH-3436-9. FHIA-23 produced bunches with a large number (294) of relatively small fruits (113.2 g).

Conclusion

The parameters, DIT and DET, did not contribute to the ranking of the hybrids or cultivars for reaction to black Sigatoka. It is difficult and time-consuming to assess these characters as stage 2 of the disease has to be recognised and each week a search has to be made for leaves marked by the symptoms. Furthermore, DSI at 6 months did not help identify the susceptible hybrids. An insufficient level of disease had developed in 6 months for the DSI data to be useful. YLS, both before and after bunching, was an effective character for differentiating hybrids or cultivars on susceptibility to black Sigatoka. DSI at bunching and harvesting were also effective in differentiating between the hybrids or cultivars.

The level of resistance in Saba decreased considerably as the leaves aged and the bunches matured. Saba had a resistant YLS response up to mid-bunch but a susceptible response at harvest. It also gave a resistant DSI response at bunching, but a highly susceptible response at harvest. A similar, but smaller, trend was evident with Yangambi Km 5 and Pisang Ceylan.

A summation of responses from the 10 characters assessed enabled the seven hybrids or cultivars to be rated as highly resistant (SH-3436-9, FHIA-23 and Yangambi Km 5), resistant (Pisang Ceylan and Saba) and highly susceptible (PV 03.44 and PA 03.22). Williams also had a highly susceptible reaction.

The agronomic features recorded for these hybrids or cultivars were influenced by both the level of disease and the cyclone Hina, which destroyed the trial before all bunches had matured. The FHIA hybrids, SH-3436-9 and FHIA-23 produced large bunches (28.8 and 36.5 kg) while the bunches on the highly susceptible hybrids from Brazil (PV 03.44 and PA 03.22) were very small (11.3 and 9.3 kg). The other “test” cultivars produced medium-size bunches. Fruit weight varied from 49 g for Pisang Berlin and 81.3 g for Yangambi Km 5, to 150.3 g for SH-3436-9 and a heavy 231.1 g for Saba. Saba produced a few (67) large fruits while FHIA-23 produced a large number (294) of medium-size fruits (113.2 g).

Table 1. Number of plants assessed for each parameter in each plot.

Variety	DIT	DDT	DET	LER	YLS no bunch	YLS bunching	YLS mid-bunch	YLS harvest	DSI 6 months	DSI bunch	DSI harvest	Days to bunch	Days to harvest
SH-3436-9	3.8	3.6	3.6	3.6	3.6	2.8	2.0	0.6	4.2	2.8	2.4	3.0	2.0
FHIA-23	4.4	4.4	4.4	4.4	4.4	3.0	0.4	0.0	4.4	2.8	1.2	2.4	0.6
Saba	5.0	5.0	5.0	5.0	5.0	5.0	4.8	3.0	5.0	5.0	4.4	5.0	4.6
Yangambi Km 5	4.8	4.2	4.2	4.8	4.4	4.0	3.0	0.6	5.0	4.0	2.4	4.4	2.8
Pisang Ceylan	4.8	4.8	4.8	4.8	4.8	4.6	3.8	0.4	5.0	4.8	3.8	4.8	4.0
PV 03.44	4.4	4.4	4.4	4.4	4.4	4.2	4.2	4.2	4.4	4.2	4.0	4.2	4.0
PA 03.22	4.8	4.8	4.8	4.6	3.8	4.4	4.2	4.4	4.6	4.8	3.0	4.8	4.4
Reference Varieties													
Calcutta IR 124	3.4	3.4	3.4	3.4	3.4	4.0	4.0	4.0	4.2	4.2	2.6	4.2	3.2
Pisang Lilin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pisang Berlin	4.8	4.0	4.0	4.6	4.0	3.8	3.8	3.8	4.2	3.8	3.8	4.2	3.8
Niyarma-Yik	2.4	2.4	2.4	2.4	2.4	2.6	1.4	1.2	3.0	2.4	2.2	2.4	1.8
Williams	4.6	4.4	4.4	4.2	4.6	3.8	3.8	3.2	4.6	3.8	3.0	3.8	3.2

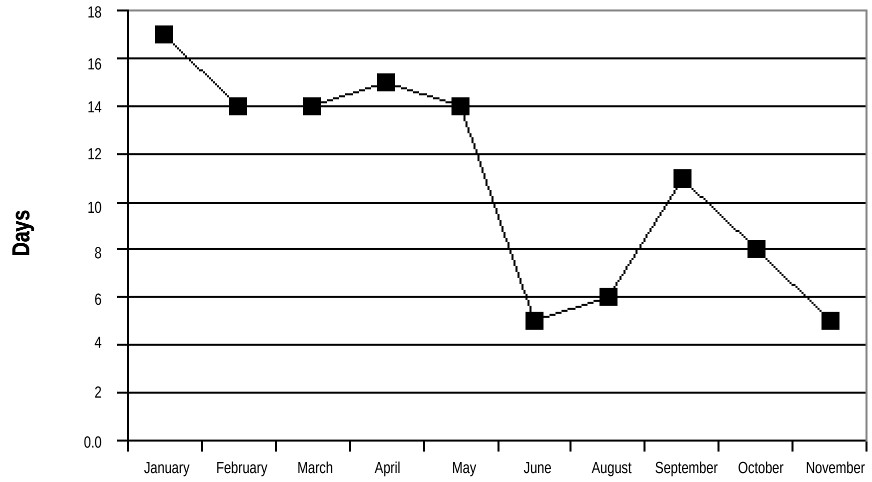
Table 2. Disease development - 4 months to bunching.

Variety		DIT	DET	DDT	YLS	LER
SH-3436-9		33	94	136	11	0.93
FHIA-23	35	92	126	11	1.03	
Saba		36	80	115	9	0.84
Yangambi Km 5		31	76	107	11	1.06
Pisang Ceylan		30	71	101	10	0.82
PV 03.44		32	31	63	7	1.01
PA 03.22		30	31	62	7	0.87
Reference Varieties						
Calcutta IR 124	ER	65	NL	NL	NL	1.03
Pisang Lilin	HR	md	md	md	md	md
Pisang Berlin	R	30	44	76	8	1.00
Niyarma-Yik	HS	24	22	45	5	1.00
Williams	HS	25	28	53	5	0.87

DDT	Disease Development Time
DET	Disease Evolution Time
DIT	Disease Incubation Time
DSI	Disease Severity Index
ER	Extremely Resistant (lesions do not develop)
HR	Highly Resistant
HS	Highly Susceptible
LER	Leaf Emergence Rate
md	missing data
NL	No mature lesions
R	Resistant
YLS	Youngest Leaf Spotted

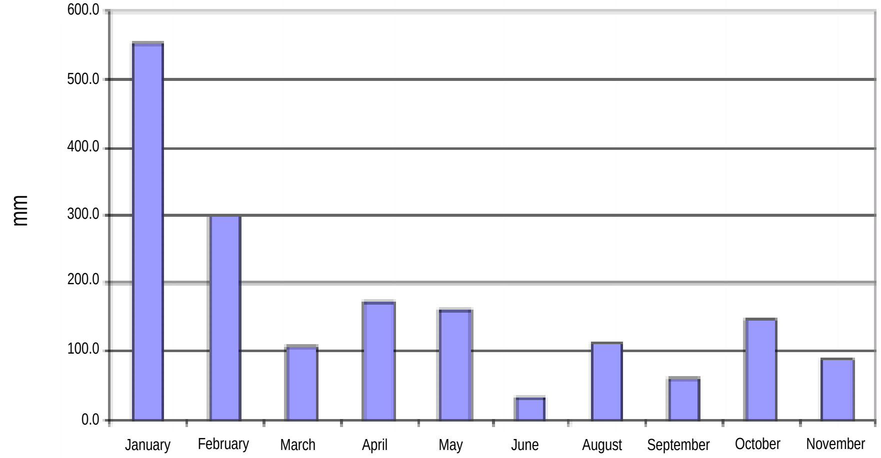
Number of wet days

Vaine Research Station 1996



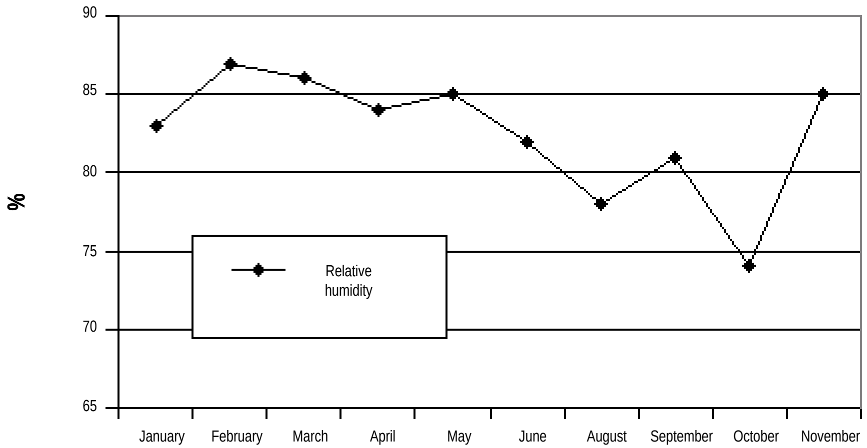
Rainfall

Vaine Research Station 1996



Relative humidity

Vaine Research Station 1996



Temperature

Vaine Research Station 1996

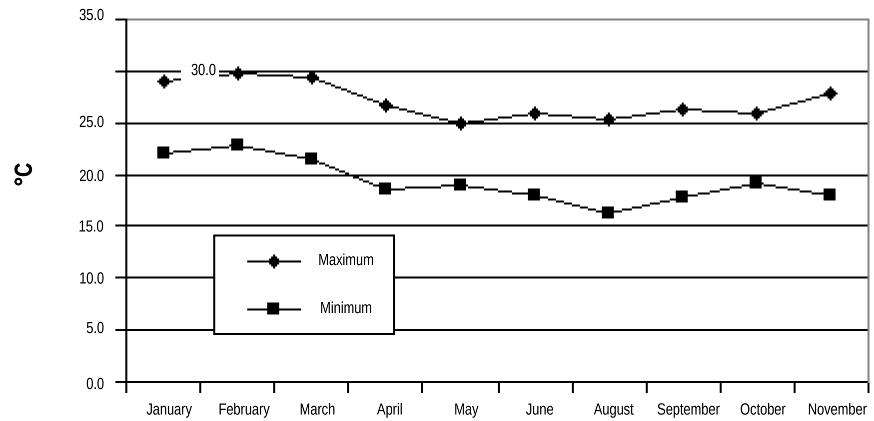


Table 3. Youngest leaf spotted - bunching to harvest.

Variety		Youngest leaf spotted Bunching	Mid-bunch	Harvest
SH-3436-9		13.3	10.8	8.0
FHIA-23		14.7	12.3	NA
Saba		9.3	7.3	4.4
Yangambi Km 5		12.2	10.5	9.0
Pisang Ceylan		11.0	9.6	7.3
PV 03.44		6.8	4.2	0.6
PA 03.22		6.6	3.8	0.4
Reference Varieties				
Calcutta IR 124	ER	NL	NL	NL
Pisang Lilin	HR	md	md	md
Pisang Berlin	R	9.2	8.1	6.9
Niyarma-Yik	HS	6.7	5.2	3.8
Williams	HS	7.2	3.3	0.1

ER Extremely Resistant (lesions do not develop)
HR Highly Resistant
R Resistant
HS Highly Susceptible
NL No mature lesions
md missing data

Table 4. Disease severity index for a range of banana hybrids/varieties.

Variety		Disease severity index 6 months	Bunching	Harvest
SH-3436-9		17.6	13.5	18.3
FHIA-23		16.9	6.1	12.1
Saba		14.8	21.5	35.1
Yangambi Km 5		18.9	20.0	17.4
Pisang Ceylan		20.1	19.0	22.0
PV 0344.		21.7	29.9	81.5
PA 03.22		21.6	34.8	98.4
Reference Varieties				
Calcutta IR 124	ER	2.5	1.8	<1
Pisang Lilin	HR	md	md	md
Pisang Berlin	R	18.1	22.7	26.3
Niyarma-Yik	HS	34.4	29.5	39.0
Williams	HS	31.2	30.0	97.2

ER Extremely Resistant (mature lesions do not develop)
HR Highly Resistant
R Resistant
HS Highly Susceptible
md missing data

Table 5. Varietal response through a range of parameters to black Sigatoka.

Variety	DIT	DET	DDT	YLS non bunch	YLS bunching	YLS mid-bunch	YLS harvest	DSI 6 months	DSI bunch	DSI harvest
SH-3436-9	R	HR	HR	HR	HR	HR	HR	R	HR	HR
FHIA-23	R	HR	HR	HR	HR	HR	md	R	HR	HR
Saba	R	HR	HR	R	R	R	S	R	R	HS
Yangambi Km 5	R	HR	HR	HR	HR	HR	HR	R	R	HR
Pisang Ceylan	R	HR	HR	R	HR	R	R	R	R	R
PV 03.44	R	HS	HS	S	HS	HS	HS	R	HS	HS
PA 03.22	R	HS	HS	S	HS	HS	HS	R	HS	HS

Table 6. Summary of varietal responses to black Sigatoka.

Variety	ER	HR	R	S	HS	Overall Rating
SH-3436-9	0	8	2	0	0	HR
FHIA-23	0	7	2	0	0	HR
Saba	0	2	6	1	1	R
Yangambi Km 5	0	7	3	0	0	HR
Pisang Ceylan	0	3	7	0	0	R
PV 03.44	0	0	2	1	7	HS
PA 03.22	0	0	2	1	7	HS

Table 7. Agronomic features of varieties.

Variety	Days to bunch	Height at bunch	Day to harvest	Height of follower	Bunch weight	No. of hands	No. of fingers	Finger weight
SH-3436-9	345	223	417	278	28.8	10	177	150.3
FHIA-23	378	md	432	278	36.5	16	294	113.2
Saba	285	257	414	323	17.1	6	67	231.1
Yangambi Km 5	330	293	427	303	16.1	9	196	81.3
Pisang Ceylan	321	287	424	326	20.3	12	191	100.8
PV 03.44	239	265	380	358	11.3	7	98	105.5
PA 03.22	256	180	396	255	9.3	6	88	97.3
Reference Varieties								
Calcutta IR 124	211	132	bunches failed to mature (sterile???)					
Pisang Lilin	*md	md	md	md	md	md	md	md
Pisang Berlin	299	186	357	161	5.3	7	91	49.0
Niyarma-Yik	333	277	362	133	8.2	7	83	87.2
Williams	304	219	366	219	22.8	10	172	121.9

* md: missing data

Results and discussion
IMTP Sigatoka
Kampala, Uganda

Wilberforce Tushmereirwe and Africano Kangire
NARO, Kawanda Agricultural Research Institute, PO Box 7065, Kampala, Uganda

Local cultivar: Mbwazirume

Environmental characteristics and particularities of design

The trial was located at Kawanda Agricultural Research Institute, near Kampala at a latitude of 0°19' N and a longitude of 32° E. On average, annual rainfall was 1 250 mm and relative humidity 76.3%. Mean daily temperatures ranged between 15.3°C and 27.6°C. The experiment was planted according to the protocol.

Williams and Pisang Lilin were dwarf somaclonal variants.

Agronomic traits

The analyses of variance showed highly significant differences among genotypes for all traits studied. In contrast, differences among blocks were significant only for plant height and the number of days from planting to shooting.

Phenology and morphology traits

The local cultivar measured 256 cm. All the genotypes were smaller than or as tall as the local cultivar. Only two genotypes had absolute higher values, FHIA-23 (284 cm) and Pisang Ceylan (275 cm), but they were not tall enough to be significantly different.

For days from planting to shooting, the local cultivar took 357 days. The only genotype that took longer to produce shoots at a significant level was FHIA-23 at 471 days. The same pattern was observed for days to harvest. The local cultivar took 504 days from planting to harvest and the only genotype with a significantly longer cycle was FHIA-23 at 651 days.

Yield and production

The local cultivar produced bunch weights of 15 kg on average. Only FHIA-23 (23.8 kg) had a higher production at a highly significant level. All other genotypes produced as much as or less than the local cultivar.

FHIA-23 was significantly superior with 12 hands, while the local cultivar produced 7 hands. For the number of fingers per bunch, the only genotype with a significantly higher fruit number than the local cultivar (107) was Yangambi Km 5 with 165 fingers. SH-3436-9 also had a very large number of fruits (125), but it was not significantly different from the local cultivar.

Response to disease

Disease development time (DDT) and the youngest leaf spotted (YLS) were taken for two generations.

In the plant crop cycle, the local cultivar had a DDT of 58.6 days, while Pisang Ceylan, the resistant reference cultivar, had a DDT of 129 days. FHIA-23 and SH-3436-9 showed a high partial resistance reaction with a DDT of 103.9 and 93.4 days respectively. The youngest leaf spotted was leaf 7 for FHIA-23 and leaf 6.4 for SH-3436-9 respectively. In comparison, the YLS of the local cultivar was 4.2.

For the second cycle, the DDT in the local cultivar increased to 85.8. DDT for most of the other genotypes increased or remained the same. The only exception was PV 03.44 in which the DDT decreased with respect to the plant crop cycle. The same was observed for the YLS. This result indicates that the pressure of the pathogen has decreased or that the genotypes show better resistance/tolerance when they are well established in the field.

Summary

FHIA-23 and SH-3436-9 are tolerant to yellow Sigatoka.

Fusarium wilt

Results and discussion
IMTP Fusarium
Wamuran, Australia

Ken Pegg
QDPI, 80, Meiers Road, Indooroopilly, QLD 4068, Australia

Local Cultivar: Williams North Queensland accession

Environmental characteristics and design

The experiment was planted in a site with a severe natural infestation of *Fusarium oxysporum* f.sp. *cubense* race 4 VCG (0120). The trial was planted on November 1995. The site was located at a latitude of 27°28’ S, a longitude of 153 02’ E and an altitude of 380 m.a.s.l. Wamuran has an average rainfall of 915 mm per year. Rainfall is bimodal with peaks in March (275 mm) and October (260 mm). The average temperature is 21°C, while mean maximum temperatures vary between 30°C in January and 20°C in June.

Clones Burro CEMSA and Saba did not survive post-entry quarantine and could not be included in the trials. As the Williams accession that ITC sent was a somaclonal variant, a local Williams accession from North Queensland was planted as the local cultivar. This accession was used for recording the agronomic traits. The experiment was planted according to the protocol in a completely randomised design.

Agronomic traits

There were highly significant differences among genotypes for all traits studied.

Phenology and morphology

Williams, which was the local cultivar, flowered 447 days from planting. All the cultivars had statistically equal or shorter cycles than the local cultivar. Among the improved cultivars FHIA-03 had the shortest cycle with 372 days and FHIA-23 had the longest one with 503 days.

For the number of days from planting to harvest, Williams had a value of 579 days. Most of the genotypes had equal or shorter cycles than the local cultivar with the exception of GCTCV 215 (675 days) and Yangambi Km 5 (667 days), which were significantly later to harvest than the local cultivar.

For plant height, Williams was 213 cm tall. Most improved cultivars were taller than Williams ($P<0.01$) with the exception of PA 03.22 (221 cm) which was not significantly different.

The landraces Pisang Mas, Pisang Jari Buaya, Gros Michel, Bluggoe and Pisang Ceylan were taller than the local cultivar ($p<0.01$).

Yield and production

Williams had an average bunch weight of 16 kg. Among the improved cultivars only FHIA-17 (24 kg) had an average bunch weight significantly superior to the local cultivar. Although other improved cultivars performed well, such as FHIA-01 (21 kg), FHIA-23 (15.5 kg), FHIA-03 (15.7 kg), GCTCV 215 (17.5 kg), their average bunch weights were not superior to that of the local cultivar to any significant level in the Dunnett test. Among the landraces it should be noted that Pisang Ceylan had an average bunch weight of 17.8 kg.

Response to disease

The external symptoms were taken during two cycles (22 months). In general, the only genotypes that presented external symptoms with a clear increasing evolution were FHIA-03, Pisang Mas, Yangambi Km 5, Gros Michel and Bluggoe. PV 03.44 also presented external symptoms but these were very mild.

The internal symptoms were taken on the ratoon cycle. The two Williams clones had disease scores of 2.24 and 2.35 respectively. Very susceptible clones were FHIA-03 (5.76), Pisang Mas (5.24), Yangambi Km 5 (5.52), Gros Michel (5.4) and Bluggoe (5.48) as shown by the external symptoms in these genotypes. Those that did not show any internal symptoms or had scores lower than 2.0 were FHIA-01, GCTCV 119, GCTCV 215, Pisang Nangka, Cultivar Rose, Pisang Jari Buaya, Pisang Lilin and Calcutta 4.

Results and discussion
IMTP Fusarium
Cruz das Almas, Brazil

Aristoteles Pires de Matos
EMBRAPA/CNPMF
Rua EMBRAPA s/n, Caixa Postal 007, Cruz das Almas 44380-000, Bahia, Brazil

Local cultivar: Prata aña

Description of experimental site

The experiment was planted in March 1996 at the experimental station of Cruz das Almas of EMBRAPA/CNPMF. The site was located at a latitude of 12°40' S, a longitude of 39°06' W and an altitude of 225 m.a.s.l. The highest temperature was 33.4°C and the lowest 18.4°C. The average temperature was 24.1°C with a rainfall of 1 083 mm per year. The soil was a sandy loam plain of pH 5.5 with good drainage.

Data were recorded on agronomic characters as specified in the protocols as well as the internal symptoms. Data on external symptoms were not recorded.

The experiment was planted in a complete randomised design with 22 treatments and 20 replicates. The spacing between plants was 3 m x 2 m.

Agronomic traits

Phenology and morphology

There were highly significant differences ($p<0.01$) between genotypes for all agronomic traits. Gros Michel was the plant with the highest number of days to shooting. The average difference was 176.25 days when compared to the local cultivar, followed by Williams, FHIA-23, FHIA-17, GCTCV 215 and GCTCV 119 (see Dunnet analysis). The number of days to shooting of the local cultivar was statistically similar to those of Bluggoe, Yangambi Km 5, Pisang Ceylan and Pisang Mas. Compared to the local cultivar, the earlier genotypes were Calcutta 4, PV 03.44 and PA 03.22.

For the number of days from planting to harvest, Gros Michel had the longest production cycle (632 days), followed by GCTCV 119 (628 days). Bluggoe, Yangambi Km 5, Pisang Mas and Pisang Nangka did not show any significant differences compared to the local cultivar. Calcutta 4 was the earliest at 405 days, but Burro CEMSA, Cultivar Rose, PA 03.22, Pisang Lilin, PV 03.44, Saba, FHIA-01 and FHIA-03 also had shorter production cycles than the local cultivar.

Bluggoe, Burro CEMSA, GCTCV 119, Gros Michel, Pisang Ceylan, Pisang Jari Buaya, Pisang Mas, Pisang Nangka, PV 03.44, Saba, FHIA-03, FHIA-23 had taller plants than the local cultivar ($p<0.01$). GCTCV 215 and FHIA-01 did not show significant differences compared to the local cultivar.

Yield and production

Yields were low, ranging from 1.72 kg for Pisang Lilin, which was a somaclonal variant and 4.66 kg for Williams to almost 20 kg for FHIA-23. Maximum yields were attained by FHIA hybrids with bunch weights ranging between 13.95 and 19.96 kg. The best yielding hybrids were FHIA-23 (20 kg), followed by FHIA-03 (19 kg) and FHIA-17 (18 kg). These bunch weights were significantly higher than that of the local cultivar. Among the landraces, Pisang Ceylan (18 kg), Burro CEMSA (18 kg) and Bluggoe (14 kg) produced the highest yields. These very low yields, together with a very long production cycle appear to be linked to the site characteristics.

Response to disease

Bluggoe presented the highest incidence of Fusarium wilt with an average of 3.29, and it also had the highest disease records. Prata aña, Gros Michel, and FHIA-03 also exhibited some degree of corm discolouration (2.77, 2.4 and 2.6 respectively).

Hybrids that did not show infection were the Brazilian PV 03.44 and PA 03.22, the FHIA hybrids FHIA-23, FHIA-17 and the Taiwanese somaclonal variants GCTCV 119 and 215. Of the seven isolates successfully collected from the samples, five belonged to VCG 0124, and one to VCG 0125 of race 1.

Summary

Calcutta 4, Cultivar Rose, GCTCV 119, GCTCV 215, PA 03.22, Pisang Lilin, PV 03.44, FHIA-17, Williams and Yangambi Km 5 are resistant to race 1 (VCG 0124 and 0125), while FHIA-23 is highly tolerant.

Results and discussion IMTP Fusarium La Lima, Cortés, Honduras

J. Mauricio Rivera and Manuel de J. Deras
FHIA, Apdo Postal 2067, San Pedro Sula, Honduras

Local cultivar: FHIA-18

Environmental characteristics and particularities of design

The evaluation was carried out at the Centro Experimental y Demostrativo de Guarumas (CEDEG), FHIA, La Lima, Honduras, located at a latitude of 15°25' N, a longitude of 87°56' W and an altitude of 31 m.a.s.l. The experiment was planted on 7 June 1996. The field had been planted with the cultivar Highgate (*Musa* AAA, subgroup Gros Michel), a highly susceptible cultivar to race 1 of Fusarium. This area was also the testing site for evaluating the reaction of selected hybrids to Fusarium wilt.

The field soil is a loam with a pH of 7. It belongs to the category of Entisols. It has good drainage. The location's highest temperature is 34.7°C, the minimum is 23.8°C and the average 25.4°C. The location was rainfed. Rainfall is 1 015 mm per year on average. However, in the first year of the experiment there was flooding whilst in the second year a drought produced strong and adverse effects on the materials, which resulted in slowing down their development to such an extent that in May 1998, replicates of around half of the genotypes had not completed the first cropping cycle.

Planting of the experiment was carried out according to the standard protocol. About 250 g of *Foc*-infected banana material was added to the bottom of the hole at planting time to increase the chances of infection.

Due to irregular distribution of soil water, two replicates that suffered badly from a lack of water were eliminated in June 1997, leaving the experiment with 18 replicates.

Weeding and deleafing were performed as needed. Fertilisation with urea was only carried out at planting (56 g/hill) and later at 3-months intervals (38 g/hill).

Agronomic traits

There are highly significant differences among genotypes for all the traits studied. Since the experiment underwent severe flooding and drought, the absolute values are not representative of the performance of the genotypes under normal conditions.

Phenology and morphology traits

The local cultivar took 502 days from planting to shooting. Among the improved cultivars, FHIA-17and GCTCV 215 shoot much later than the local cultivar at a highly significant level. Among the landraces, Gros Michel (605 days) was the last to flower, followed by Pisang Jari Buaya (603 days), Pisang Mas (579 days) and Yangambi Km 5 (572 days). All these genotypes were statistically later than the local cultivar showing their susceptibility to stress.

For the number of days from planting to harvest, no genotypes were found to be later than the local cultivar. Since the Dunnett test is a one-sided one, it is not possible to say which ones were statistically earlier at a significant level. However, it is to be noted that the Brazilian cultivars, PV 03.44 and PA 03.22 were the earliest to be harvested.

Yield and production traits

The local cultivar produced a bunch weighing 14 kg. The only improved cultivar that produced a higher yield was FHIA-03 (18.5 kg). In general, yields were very poor due to the stress conditions of the experimental field.

Response to disease

The plants did not show any external symptoms so the usual graphs are not presented. Moreover, as the internal symptom scores in the corm were very low and there were no differences among genotypes, a comparison of means for this trait is not relevant.

Results and discussion
IMTP Fusarium
West Sumatra, Indonesia

Lilik Setyobudi
RIF, PO Box 5, Jl Solok Aripan 27301 Solok West Sumatra, Indonesia

Local cultivar : Kepok

Environmental characteristics and design

The experimental site was on a slope in Aripan, Solok in West Sumatra at a latitude of 0°N, a longitude of 100°36'E and an altitude of 415 m.a.s.l. The soil is of the clay type of Alvisols with moderate to good drainage. The field was rainfed. Rainfall was 1 358 mm per year on average. The highest average temperature was 32°C and the lowest average temperature was 18°C with an annual average of 26.5°C. The experiment was planted according to the IMTP protocol in a completely randomised design on 15 April 1996. Plant spacing was 3 m x 2 m. Ten replicates were planted instead of 20.

Agronomic traits

There were highly significant differences among the genotypes as shown by the analyses of variance. The final analysis was carried out with only few replicates as the others died.

Phenology and morphology

The local cultivar took on average 249 days from planting to shooting. Most of the improved genotypes had equal or shorter cycles than the local cultivar except for FHIA-23 (400 days) and GCTCV 119 (456 days).

For the number of days from planting to harvest only FHIA-23 had a longer cycle than the local cultivar with an average of 499 days. All other improved cultivars' production cycles were not any longer than that of the local cultivar at a significant level.

For plant height, the local cultivar measured 210 cm. All the genotypes, improved and landraces were of equal height or smaller than the local cultivar. Clones Pisang Lilin and Williams were dwarf somaclonal variants at 98 cm and 89 cm respectively.

Yield and production

The local cultivar had an average bunch weight of 5.5 kg. Most genotypes had equal or lower yields than the local cultivar except for FHIA-01 (11.3 kg) and FHIA-03 (14.3 kg). For the number of hands, only Pisang Ceylan (10.1) had a greater number of hands than the local cultivar (7) at a significant level.

All the cultivars had an equal or lower fruit number than the local cultivar (100). Although most of the improved cultivars had a greater average fruit weight than the local cultivar, only FHIA-01 (90 g) and FHIA-03 (118 g) were significantly superior than the local cultivar. As expected Saba, Bluggoe and Pisang Nangka were also significantly superior to the local cultivar.

Response to disease

Of the 10 isolates of *Foc* successfully recovered from the samples, 10 belong to the known race 4 (VCG 01213/16). An isolate belonging to a second VCG was identified in cultivar Kepok at this site

(VCG 01219). There were no significant differences among the various genotypes with respect to their internal symptoms score. This result was clearly reflected by the development of external symptoms which were very mild and did not have a clear upward trend.

Summary

It was not possible to determine susceptible or resistant accessions.

Results and discussion
IMTP Fusarium
Johor, Malaysia

Siti Hawa Jamaluddin
MARDI, PO Box 12301, Kuala Lumpur 50774, Malaysia

Local cultivar: Pisang Berangan

Environmental characteristics and particularities of design

The experiment site was in Kotta Tinggi, Johor at a latitude of 1°37' N, a longitude of 103°56' E and an altitude of 30 m.a.s.l. The soil was clay loam with a pH of 5.2 that belongs to the Ultisols type. Drainage was moderate. The experimental site was irrigated. The experiment was planted on 25 April 1996 according to the standard protocols. Only the agronomic data were given to INIBAP for this analysis.

Agronomic traits

This report includes the agronomic data for the plant crop and first ratoon. Tables with averages and coefficients of variance are presented for both cycles. Comparisons of means with the local cultivar (Dunnett analysis) are presented for the plant crop cycle only, since data for the local cultivar are not available for the first ratoon. Comparisons of means for the plant crop cycle may not be accurate as only one replicate of the local cultivar was used.

Phenology and morphology traits

The local cultivar flowered 245 days after planting. Only Saba (373 days) had a significantly longer cycle than the local cultivar. The same was true for the number of days from planting to harvest – Saba was the latest genotype to be harvested (470 days).

The local cultivar was 285 cm tall. None of the hybrids were significantly taller than the local cultivar. Among the landraces, only Saba was significantly different at 348 cm.

Yield and production

The only improved cultivars that produced significantly superior bunches to the local cultivar (11 kg) were the FHIA hybrids. FHIA-17 produced the biggest bunch at 24 kg followed by FHIA-03 (23 kg), FHIA-23 (21 kg) and FHIA-01 (21 kg). Data for the second cycle are also given.

Results and discussion IMTP Fusarium Santo Tomas Davao del Norte, Philippines

Lydia Magnaye and Concepcion E. Soguilon
BPI, Bago Oshiro, Davao City 8000, Philippines

Local cultivar: Latundan

Environmental characteristics and particularities of the site

Sto Tomas is located at a latitude of 7°30' N, a longitude of 125°39'E and an altitude of 39 m.a.s.l. It is a plain land with clay loam and a pH of 6.7. Soil drainage is good. The experiment was irrigated. Average temperature was 27°C and average relative humidity was 84%. Rainfall was 3 416 mm per year, distributed evenly throughout the year with a small peak during April.

There were no special arrangements made to the standard design of the experiment. Pisang Lilin and Williams were weak and dwarf somaclonal variants.

Agronomic traits

Phenology and morphology traits

The local cultivar took 272 days to flower and 370 days to harvest. Among the improved genotypes, GCTCV 119, GCTCV 215, and FHIA-23 were later than the local cultivar for flowering with 312, 321 and 316 days respectively. GCTCV 215 and FHIA-23 were also later than the local cultivar for days to harvest at a significant level. The other genotypes were no different from or were earlier than the local cultivar for both traits.

For plant height, none of the improved genotypes were taller than the local cultivar at a highly significant level.

Yield and production

The analysis of variance showed that there are highly significant differences among the genotypes for bunch weight. The local cultivar yielded 16.3 kg. All the FHIA hybrids were significantly superior than the local cultivar for this trait, FHIA-23 (26.1 kg), FHIA-03 (27.6 kg), FHIA-01 (20 kg) and FHIA-17 (27.7 kg).

Landraces that produced significantly superior yields than the local cultivar were Saba (27.6 kg), Burro CEMSA (25.7 kg), Bluggoe (22.7) and Pisang Nangka (21.2 kg). The clone Gros Michel did not differ from the local cultivar.

Response to disease

Of the four isolates successfully recovered from this site, two belonged to race 4 VCG 0122. Clone Williams was the susceptible reference clone for this race, but it did not present any external symptoms and had an average plant disease internal symptom score of 1.56 with a maximum internal score of 2. Only GCTVC 119 had a significantly lower average score than Williams and only Pisang Lilin showed a significantly higher score than Williams. It is not useful to compare the responses to disease in this experiment given that not even the susceptible genotype was mildly affected by Fusarium. These results are probably due to a low level of pathogen pressure.

Results and discussion IMTP Fusarium Hazyview, South Africa

Zaag de Beer
ITSC/ARC, Private Bag X501, Kiepersol 1241, South Africa

Local cultivar: Cavendish

Environmental characteristics and particularities of design

The evaluation was carried out in a farmer's field in Hazyview, Eastern Transvaal, 40 km from the ITSC experimental station at a latitude of 25°07' S, a longitude of 31°05' E and an altitude of 722 m.a.s.l. The Hazyview area is well-known for its high Fusarium wilt infestation (race 4).

The field soil was a clay loam with a pH of 5.1 that belongs to the Oxysol type. It had good drainage and no slope. The location's highest temperature was 28°C, the lowest temperature 10.5°C and the average 23.3°C. The trial was both irrigated and rainfed. Rainfall was 963 mm per year.

Planting of the experiment was carried out according to the standard protocol with a 2 m x 1 m x 5 m spacing. Weeding and deleafing were performed when necessary. The experiment lost some replicates due to herbicide applications.

Agronomic traits

The analyses of variance were highly significant for all the traits studied.

Phenology and morphology traits

The number of days from planting to shooting was highly variable even within genotypes, as is apparent in the respective graphs. Many data points fall outside the box area which represents three quartiles. These outliers are represented by asterisks. The local cultivar took 583 days from planting to shooting. The only improved cultivars that produced shoots later than the local cultivar were GCTCV 119 (740 days) and GCTCV 215 (706 days). All the others were similar to or earlier than the local cultivar.

Among the landraces, Williams (686 days), Yangambi Km 5 (677 days), Pisang Jari Buaya (656 days) and Pisang Nangka (656 days) were significantly later than the local cultivar.

For days from planting to harvest, the only genotypes that had a longer cycle than the local cultivar (712 days) were GCTCV 119 (811 days) and GCTCV 215 (805 days). Other cultivars had longer cycles but they were not significantly longer than that of the local cultivar.

The plant height of the local cultivar was 229 cm. Among the improved cultivars, FHIA-03 (279 cm), FHIA-17 (273 cm), FHIA-23 (283 cm) and PV 03.44 (307 cm) were significantly taller than the local cultivar. Among the landraces, Gros Michel was the tallest (358 cm) although only 2 plants were evaluated. Gros Michel was followed by Pisang Ceylan (325 cm), Pisang Jari Buaya (325 cm), Saba (307 cm), Burro CEMSA (302 cm), Bluggoe (292 cm) and Pisang Nangka (288 cm). The number of plants evaluated was very variable.

Yield and production

In general, yields were medium to poor. The local cultivar produced a 15 kg bunch on average. Though FHIA-17 produced a 17.7 kg bunch, FHIA-01 a 16.2 kg bunch and Saba a 16 kg bunch, no genotype produced a significantly bigger bunch than the local cultivar.

For the number of hands and fruit number, FHIA-17 was significantly superior to the local cultivar though its average fruit weight was inferior. As was expected, only the average fruit weight for Saba and Burro CEMSA was highly superior to that of the local cultivar.

Response to disease

The internal symptom score was assessed in most replicates. Williams was used as a control and had a score of 1.37. FHIA-03 and FHIA-23 had a higher infection index at a significant level. Among the improved cultivars which did not have any corm infection were PV 03.44, PA 03.22 and GCTCV 119. Other genotypes that did not have any corm infection were Burro CEMSA, Pisang Nangka, Cultivar Rose, Pisang Jari Buaya, Pisang Ceylan, Pisang Mas and Calcutta 4. The only landrace that had a higher infection score than Williams was Yangambi Km 5.

Nineteen isolates were recovered from this site. All belonged to the known race 4 VCGs 0120 and 0120/15.

Summary

GCTCV 119, PV 03.44 and PA 03.22 are resistant to Fusarium wilt under South African conditions.

Results and discussion
IMTP Fusarium
Canary Islands, Spain

Julio Hernandez
ICIA, Apartado de correo 60, 38200 La Laguna,
Tenerife, Islas Canarias, Spain

Local cultivar: Grande Naine

Environmental characteristics and particularities of design

Valle de Guerra in Tenerife, Canary Islands is a valley located at a latitude of 20°31' N, a longitude of 18°22' W and an altitude of 50 m.a.s.l. The soil is clay-clay loam with a pH of between 6-7 that belongs to the Hallosyte type. Soil drainage is poor so the trial was irrigated.

Temperature varied between 13 and 26.6°C with an annual average of 19.6°C and a maximum average of 23°C in September. Rainfall was monomodal with a peak of about 5 000 mm between December and January.

The experimental design followed the protocol plant spacing but the trial was split into two adjacent plots. Due to plant quarantine regulations, the trial could only be planted when the cold season had started and initially plants suffered from the low temperature.

External symptoms were recorded from the 6th month after planting instead of from the 3rd month. Clones Williams and Pisang Lilin were dwarf somaclonal variants. No desuckering was carried out.

Agronomic traits

Phenology and morphology traits

The local cultivar took 348 days on average from planting to shooting. The only improved cultivar which had a statistically significant longer cycle than the local cultivar was FHIA-17 with 559 days. Two landraces also had significantly longer cycles than the local cultivar, e.g. Bluggoe (491.2 days) and Pisang Jari Buaya (510 days). The other genotypes were not different from the local cultivar at a significant level.

For plant height most of the genotypes were taller than the local cultivar (202.5 cm) except for Calcutta 4 (205 cm), Cultivar rose (210 cm) and PA 03.22 (221 cm), which were not statistically different from the local cultivar.

Yield and production

Yields were low due to the particular conditions under which the trial was planted and also because plants were not desuckered.

The local cultivar had smaller bunches than usual (11.3 kg). Most genotypes had either lower yields than the local cultivar or did not differ at a significant level. Only FHIA-17 (18.5 kg) produced a significantly bigger bunch than that of the local cultivar.

Response to disease

Genotypes that did not present any internal symptoms were Calcutta 4, Cultivar Rose, GCTCV 119, Pisang Jari Buaya and Pisang Lilin.

The hybrids that had the lowest average scores were FHIA-17 with 2.3 and PA 03.22 with 2.4. Williams, which is the susceptible reference clone for race 4, had an average of 2.9. The other genotypes had higher average scores and were rated as susceptible on this site. Sixteen isolates of *Foc* were recovered from the samples sent to QDPI. According to the VCG analysis, the isolates belonged to the known race 4 VCGs 0120 and 0120/15.

Summary

All hybrids showed a susceptible reaction to Fusarium wilt race 4 VCG 0120 and 0120/15.

Results and discussion IMTP Fusarium Pingtung, Taiwan

Ching-Yan Tang
TBRI, PO Box 18, Chiuju, Pingtung 90403, Taiwan

Local cultivar: Tai Chiao # 2: semi-dwarf Cavendish

Environmental characteristics and particularities of design

The TBRI experimental station is located in the south of Taiwan at a latitude of 22°42' N and a longitude of 120°29' E. It is a plain of loam soil that has a pH of 5.0 to 5.3 and moderate soil drainage. The fields were rainfed and irrigated. The trial was planted in May 1996 when minimum temperatures were around 22°C and the maximum were around 30°C. Rainfall was 1,600 mm per year, monomodal, with its peak in August (600 mm).

The experimental design was as specified in the protocol, though with 14 replicates instead of 20. Due to a shortage of land, this trial was planted at a higher density than in normal conditions. Cultivars that were less vigorous suffered by being shaded by more vigorous ones.

Agronomic traits

As expected, all analyses of variance were highly significant for genotypes.

Phenology and morphology traits

Pisang Jari Buaya was the tallest landrace (433 cm), followed by Saba (409 cm), Burro CEMSA (404 cm), Bluggoe (402 cm) and Pisang Ceylan (383.08 cm).

Among the hybrids, the tallest was FHIA-23 at 376 cm followed by PV 03.44 at 371.63 cm and FHIA-03 at 365 cm. The hybrids that were smaller than the local cultivar were FHIA-01 at 289.3 cm and PA 03.22 at 252 cm. The cultivar Williams was not considered for discussion because it was a dwarf somaclonal variant.

The local cultivar took 293 days from planting to shooting and 115 more days to harvesting (408 days). Hybrids FHIA-01, FHIA-03 and PA 03.22, PV 03.44 and GCTCV 215 were earlier than or not different from the local cultivar for shooting. None of the genotypes differed from the local cultivar for the number of days to harvest.

Yield and production

The local cultivar produced a bunch of 26.75 kg. In comparison to this, FHIA-23 produced a bunch weighing 47 kg and FHIA-17 44 kg. These two hybrids produced bunches that were bigger than that of the local cultivar at a highly significant level. If we note the number of days to harvest of these hybrids compared to the local cultivar, FHIA-17 was 7.4 days earlier than the local cultivar and FHIA-23 was later by 9.8 days, however, this difference was not significant. The earliness of these hybrids combined with their high yields make them extremely productive.

Cultivars GCTCV 215 and 119 attained their usual yields at around 20 kg and 22 kg respectively. Although the average yield of GCTCV 119 (23 kg) surpassed that of the local cultivar, it was not statistically different. This result was probably due to the small number of experimental units and large standard deviation of the local cultivar.

Yields are highly correlated with the fruit number, number of hands and average fruit weight. FHIA-23 had the highest fruit number (282), while the local cultivar only had 190.

Response to disease

Hybrids FHIA-01, FHIA-03 and FHIA-23 did not present external symptoms in a consistent manner or, if they did, these were slight and only in the early months after planting. The percentage of plants of these genotypes presenting mild symptoms was lower than 1%. Similarly these hybrids had low scores for internal symptoms. FHIA-01 did not present any internal symptoms.

Tissue culture variants GCTCV 215 and 119 only showed mild external symptoms. When present, symptoms were mild and only 3 to 4 plants showed severe splitting or vascular discolouration. GCTCV 215 consistently marked an average score of 1.2 for internal symptoms. No plants of this genotype presented a score higher than 3. GCTCV 119 showed a slightly higher average score of 2.28.

Hybrids PV 03.44 and PA 03.22 increasingly presented symptoms throughout the cycle, and PA 03.22 in particular had severe symptoms of shortened internodes, splitting of pseudostem, vascular discolouration and wilting. This phenotype was consistent with its internal symptoms' average score of 4.28.

Gros Michel as the susceptible reference clone for race 1 presented extensive and severe symptoms throughout the cycle. When examined for internal symptoms, it had an average score of 5.85.

Among the landraces showing fewest external symptoms were Calcutta 4, Cultivar Rose and Pisang Jari Buaya. These results were consistent with the average score for internal symptoms. Of the 16 isolates of *Foc* characterised using vegetative compatibility analyses and volatile production, 12 belonged to the known race 4 VCGs 0121 and 01213/16.

Summary

From the results of this trial, FHIA-01, GCTCV 215, Cultivar Rose, Pisang Jari Buaya and Calcutta 4 can be considered resistant to race 4 VCGs 0121 and 01213/16. FHIA-23 and FHIA-17 can be considered tolerant given that, although infected, they produced high yields.

Results and discussion
IMTP Fusarium
Kampala, Uganda

Africano Kangire
NARO, Kawanda Agricultural Research Institute
PO Box 7065, Kampala, Uganda

Local cultivar: Mbwazirume

Environmental characteristics and particularities of design

The evaluation was carried out in a farmer's fields in the Kichwamba sub-county (Bushenyi district), which is located 400 km southwest of Kampala. The fields were originally infested with Fusarium wilt and plants of Pisang Awak, Ney Poovan and Gros Michel were chopped and mixed with the soil.

The environment data were not taken at the actual location of the trial. The data available were taken at the nearest location (neighbouring county, Ryeru, also in Bushenyi district), about 15 kilometres from the trial. Data on relative humidity are not available. The average highest temperature was 27.7°C while the absolute highest was 35.5°C. The average lowest temperature was 14.1°C and the absolute lowest 12.3°C. The fields were rainfed. Rainfall ranged between 1 000 and 2 000 mm per year.

The experiment was planted on 1 December 1995. Only 15 replicates were planted. As the field was managed by farmers, only a few agronomic traits were recorded. These are: harvest date, bunch weight, number of hands and fruit number. No external symptoms were recorded.

Agronomic traits

There were highly significant differences among the genotypes for all the traits studied. Clones Williams and Pisang Lilin were somaclonal variants.

Phenology and morphology traits

The cycles were very long, always more than 500 days. This result can be explained by the conditions of farmers' fields and the absence of fertilisers.

Yield and production traits

The local cultivar produced a 17 kg bunch on average. The four FHIA clones, FHIA-01, FHIA-03, SH-3649 and FHIA-23 had excellent yields. The best yielder was FHIA-17 with an average bunch weight of more than 39 kg. Three hybrids, FHIA-03 (28 kg), FHIA-17 (39 kg) and FHIA-23 (37 kg) were significantly superior than the local cultivar. Only FHIA-01 did not present significant differences for bunch weight. For the number of hands, FHIA-17 (12 hands) and FHIA-23 (12 hands) were significantly superior to the local cultivar (8 hands).

Response to disease

Gros Michel was the most susceptible clone with an average score of 3.22. All other genotypes had average scores inferior to 2.0. It was not possible to characterise the isolates using vegetative compatibility analyses.

Site managers

Catherine ABADIE
CRBP / CIRAD
BP 832
Douala
CAMEROON
Tel: (237) 4252 60
Fax: (237) 4257 86
e-mail: abadie@cirad.fr

Marilyn ALFORQUE
BPI
Bago, Oshiro
Davao City 8000
THE PHILIPPINES
Tel: (63) 82 29 30 107
Fax: (63) 82 29 30 107
e-mail:banphil@dv.weblinq.com

José Manuel ALVAREZ ACOSTA
Ministerio de la Agricultura
Calle: Conill, esquina Boyeros
Plaza de la Revolución
Ciudad de la Habana
Tel: (53) 7 81 8397
Fax: (53) 7 335086
e-mail: julito@minag.gov.cu

Gerado CAYON
CORPOICA
Av. Bolívar
Sector Regivit 28 Norte
A.A.1807
Armenia Quindío
COLOMBIA
Tel: (57 67) 49 34 98
Fax: (57 67) 49 63 31
e-mail: corpoarm@armenia.multi.net.co

Julio COTO
FHIA
Apdo Postal 2067
San Pedro Sula
HONDURAS
Tel: (504) 6 68 20 78
Fax: (504) 6 68 23 13
e-mail: dinvest@simon.intertel.hn

Zaag DE BEER
Institute for Tropical and Subtropical Crops / Agricultural Research Council
Private Bag X11208
Nelspruit 1200
SOUTH AFRICA
Tel: (27) 13 753 2071
Fax: (27) 13 752 3854
e-mail: zaag@itsc.agric.za

Henry FAGAN
WIBDECO
Manoel Street
Compton Bldg
PO Box 115
Castries
SAINT LUCIA
Tel: (1) 75 845 14255 / 4242
Fax: (1) 75 845 14242

Eric FOURE
CRBP / CIRAD
BP 832
Douala
CAMEROON
Tel: (237) 4252 60
Fax: (237) 4257 86
e-mail: foure@cirad.fr

Mauricio GUZMAN
CORBANA
Apartado 390 7210
Guápiles
COSTA RICA
Tel: (506) 763 3257
Fax: (506) 763 3055
e-mail: investigaciones@corbana.com

Julio HERNANDEZ
ICTA
Apartado de correo 60
38200 La Laguna
Tenerife, Canary Islands
SPAIN
Tel: (34) 922 47 63 55
Fax: (34) 922 47 63 03
e-mail: jhernand@icia.rcanaria.es

Lorna HERRADURA
BPI-DNCRDC
Bago Oshiro
Davao City 8000
THE PHILIPPINES
Tel: (63) 82 29 30 107
Fax: (63) 82 29 30 107
e-mail: banphil@dv.weblinq.com

Siti Hawa JAMALUDDIN
MARDI
PO Box 12301
Kuala Lumpur 50774
MALAYSIA
Tel: (60) 3 9437 189
Fax: (60) 3 948 7 590
e-mail: sitihawa@mardi.my

Africano KANGIRE
NARO KARI
PO Box 7065
Kampala
UGANDA
Tel: (256) 415 67 158
Fax: (256) 412 34 922
e-mail: banana@imul.com

Lydia MAGNAYE
BPI
Bago Oshiro
Davao City 8000
THE PHILIPPINES
Tel: (63) 82 2930107
Fax: (63) 82 2930107
e-mail: banphil@dv.weblinq.com

Sonthat NANTHACHAI
HRI
Chatuchak
10900 Bangok
THAILAND
Tel: (66) 2579 5582
Fax: (66) 2561 4667
e-mail: hortdoa@doa.go.th

Ken PEGG
Plant Pathology Bldg
QDPI
80 Meiers Rd
Indooroopilly
QLD 4068
AUSTRALIA
Tel: (61) (0)7 3896 9341
Fax: (61) (0)7 3896 9533
e-mail: peggk@dpi.qld.gov.au

Ron PETERSON
QDPI
PO Box 1054
Mareeba QLD 4880
AUSTRALIA
Tel: (61) (0)7 4092 8555
Fax: (61) (0)7 4092 3593
e-mail: petersRA@dpi.qld.gov.au

Aristoles PIRES DE MATOS
EMBRAPA / CNPMF
Rua EMBRAPA s / n
Caixa Postal 007
Cruz das Almas 44380-000
Bahia
BRAZIL
Tel: (55) 75 7212120
Fax: (55) 75 721 1118
e-mail: apmatos@cnpmf.embrapa.br

Mauricio RIVERA
FHIA
Apdo Postal 2067
San Pedro Sula
HONDURAS
Tel: (504) 6 68 2078
Fax: (504) 6 68 2313
e-mail: dinvest@simon.intertel.hn

Lilik SETYOBOUDI
RIF
PO Box 5
JI Raya Solok-Aripan
27301 Solok West Sumatra
INDONESIA
Tel: (62) 755 23291
Fax: (62) 755 20592
e-mail: rif@padang.wasantara.net.id

P. SUNDARARAJU
NRCB
No. 44 Ramalinga Nagar
South Extension
Vayalur Rd
PO Box 620017
Tiruchirapalli Tamil Nadu
Trichy
INDIA
Tel: (91) 431 771 299
Fax: (91) 431 770 564
e-mail: nrcb@trichy.tn.nic.in

Ching-Yan TANG
TBRI
PO Box 18 Chiuju
Pingtung 90403
TAIWAN
Tel: (886) 8 7392111 to 13
Fax: (886) 8 7390595

Abdou TENKOUANO
IITA
Carolyn House
26 Dingwall Road
Croydon CR9 3EE
UK
Fax: (871) 682 341 882
e-mail: a.tenkouano@satmail.bt.com

Wilberforce TUSHMEREIRWE
NARO / KARI
PO Box 7065
Kampala
UGANDA
Tel: (256) 41567158
Fax: (256) 41 567635
e-mail: banana@imul.com

Paelata VI NAI
MAFF
PO Box 14
Nuku'Alofa
Tonga
Tel: 676 32 125
Fax: 676 32 132