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• FIFTEEN YEARS OF •

1985

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2000

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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.

INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a Future Harvest center.

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Early tests for selection

Screening *Musa* hybrids for resistance to *Radopholus similis*

Carine Dochez, Paul R. Speijer†, John Hartman†, Dirk Vuylsteke† and Dirk De Waele

Plant parasitic nematodes are a major constraint to sustainable *Musa* production (Stover and Simmonds 1987). In Uganda, which is the world’s largest producer of East African highland bananas (*Musa* spp., AAA group) (Lescot 1998), nematodes have been identified as a major factor contributing to declining production (Speijer et al. 1999). The most destructive nematode attacking bananas in the tropics is *Radopholus similis* (Cobb) Thorne (Gowen 1993), which was accordingly used as the test species in this screening procedure.

Nematodes can be controlled with chemicals, but these may have adverse environmental effects and the use of nematicides is too expensive and the products too dangerous for subsistence farmers. Breeding for host plant resistance is a promising strategy for controlling nematodes (Speijer and De Waele 1997). However, screening new hybrids in the field is very time- and space-consuming. Therefore, an early method for screening banana germplasm for nematode resistance, based on inoculation of individual roots, was used (De Schutter et al., in preparation).

**Materials and methods**

Screen-house experiments were established in Central Uganda at the Eastern and Southern Africa Regional Centre of the International Institute of Tropical Agriculture (IITA-ESARC), Sendusu Farm, Namulonge. The station is at an altitude of 1150 m asl and is representative for the East African highland bananas.

Tested cultivars included the reference cultivars Yangambi km 5 (*Musa* AAA group), which is highly resistant to *Radopholus similis*, Gros Michel (*Musa* AAA, partially resistant to *R. similis*) and Valery (*Musa* AAA, susceptible to *R. similis*).

Several hybrids were selected by the IITA-ESARC breeding programme for testing, including: the plantain derived diploid hybrids TMP2x 25215-31, TMP2x 47, and TMP2x 50; the banana derived diploid hybrids TMB2x 14115-2, TMB2x 14115-10, TMB2x 2559S-1 and TMB2x 2559S-2; the ‘Pisang Awak’ derived tetraploid hybrid TMBx 20945S-1; and the East African Highland Banana derived tetraploid hybrid TMHx 660K-1.

Nematode inoculum was obtained from *Radopholus similis* disc cultures (Pinochet et al. 1995). Carrots were surface-sterilized by spraying them with 96% ethanol followed by flaming, peeled, cut in discs (3 mm thick) and placed in 35 mm-diameter Petri dishes. Nematodes were surface-sterilized with aqueous streptomycin sulphate (2000 ppm) for 6 hours followed by three rinses with sterile distilled water. About 100 nematodes, in 10 μl of water, were placed on each carrot disc. The Petri dishes were sealed with parafilm and incubated at 28°C in the dark. Nematodes were sub-cultured onto fresh carrots every 5 to 7 weeks. Nematodes were counted. For each cultivar the reproduction ratio (final population/initial population) of *R. similis* was calculated. Orthogonal contrasts (SAS 1997) of the test materials to the reference cultivars Yangambi km 5 and Valery were run to compare the mean reproduction ratios.

**Results and discussion**

Table 1 shows the reproduction ratio of *R. similis* on the different cultivars, while Table 2 shows the orthogonal contrasts between the test cultivars and the resistant and susceptible checks. The nematodes on all the other cultivars showed a lower reproduction ratio than on Valery (Tables 1 and 2). The genotypes Gros Michel, TMP2x 25215-31 and 47, TMB2x 14115-10, TMBx 20945S-1, TMHx 660K-1 and TMB2x 2569S-2 supported a reproduction ratio that was not significantly different from that on Yangambi km 5. Genotypes with a reproduction ratio not statistically different from Yangambi Km5 support low densities and are therefore promising.

**Table 1. Reproduction ratio of *Radopholus similis* on individual roots of 12 *Musa* genotypes, 8 weeks after inoculation with a suspension containing 50 females of *R. similis***

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Parents</th>
<th>PF</th>
<th>R2r = PF2/rP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yangambi km5</td>
<td>1</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Gros Michel</td>
<td>82</td>
<td>1.64</td>
<td></td>
</tr>
<tr>
<td>Valery</td>
<td>883</td>
<td>17.66</td>
<td></td>
</tr>
<tr>
<td>TMB2x 14115-2*</td>
<td>TMB2x 7197-2 x TMB2x 9839-1</td>
<td>427</td>
<td>8.54</td>
</tr>
<tr>
<td>TMB2x 14115-10*</td>
<td>TMB2x 7197-2 x TMB2x 9839-1</td>
<td>10</td>
<td>0.20</td>
</tr>
<tr>
<td>TMB2x 25695-1*</td>
<td>TMB2x 7197-2 x TMB2x 9128-3</td>
<td>2</td>
<td>0.04</td>
</tr>
<tr>
<td>TMB2x 25695-2*</td>
<td>TMB2x 7197-2 x TMB2x 9128-3</td>
<td>491</td>
<td>9.82</td>
</tr>
<tr>
<td>TMBx 20945-1*</td>
<td>Kayinja x TMB2x 7197-2</td>
<td>73</td>
<td>1.46</td>
</tr>
<tr>
<td>TMP2x 25215-31*</td>
<td>TMP2x 1518 x TMB2x 8075-3</td>
<td>66</td>
<td>1.32</td>
</tr>
<tr>
<td>TMP2x 25215-47*</td>
<td>TMP2x 1518 x TMB2x 8075-3</td>
<td>60</td>
<td>1.20</td>
</tr>
<tr>
<td>TMP2x 25215-50*</td>
<td>TMP2x 1518 x TMB2x 8075-3</td>
<td>0.3</td>
<td>0.006</td>
</tr>
<tr>
<td>TMHx 660K-1</td>
<td>Enzirahambah x Calcutta 4</td>
<td>99</td>
<td>1.98</td>
</tr>
</tbody>
</table>

1. Rr = Reproduction ratio (final population/initial population).
2. PF = Final population including all vermiform stages and sexes.
3. Pi = Initial population, 50 females of *R. similis*.
4. Hybrids with Pisang Jat Rusya in their pedigree.
ing genotypes for further evaluation. Except for the hybrid TMHx 660K-1, all the other hybrids have Pisang Jari Buaya (Musa AA) in their pedigree, which is highly resistant to R. similis (Pinochet 1988).

Acknowledgements

Financial support by the Flemish Association for Development Cooperation and Technical Assistance (VWOB) and by the Belgian Administration for Development Cooperation (BADC) is gratefully acknowledged. The authors wish to thank Mrs Pamela Mpirirwe and Ms Christine Kajumba for technical assistance. This is IITA manuscript number IITA/00/JA/29.

References

De Schutter B., P.R. Speijer, C. Dochez, A. Tenkouano & D. De Waele. (in preparation). Screening of Musa germplasm for resistance to nematodes by inoculating individual roots.

Genotypic differences in Musa spp. root traits have been investigated under hydroponic conditions (Swennen 1984, Swennen et al. 1986) with the conclusion that dessert bananas had a larger root system than plantains. In a similar study, genotypic differences in lateral root initiation were also observed (Draye et al. 1999).

Ploidy level may influence the size of different plant parts in Musa species.
(Simmonds 1962 and 1966, Vandenhout et al. 1995), but no systematic study on the effect of ploidy level and genome group on root traits of field grown plants has been carried out.

The objective of this study was to assess the relative contribution of ploidy status and genome composition to the variability of root traits in Musa.

**Materials and methods**

This study was carried out at the IITA High Rainfall station at Onne in southeastern Nigeria (4°42' N, 7°10' E, 5 m asl). Its soil is an ultisol derived from coastal sediments, well drained but poor in nutrients and with a pH of 4.3 in 1:1 H2O. The average annual rainfall is 2,400 mm distributed monomodally from February until November. Details of the site have been described by Ortiz et al. (1997).

Eighteen genotypes (Table 1) belonging to 5 genomic groups and 3 ploidy levels of banana and plantain (Musa spp.) were assessed at flower emergence. In vitro-derived plants were produced following standard shoot-tip culture techniques (Vuylsteke 1989, Vuylsteke 1998). Rooted plantlets were transferred to polybags (height = 25 cm, circumference = 44 cm) in a greenhouse nursery (Vuylsteke and Talengera 1998, Vuylsteke 1998) and transplanted to the field during June 1996, six weeks after acclimatization.

The trial site, which had been under grass fallow for a period of 8 years, was manually prepared in order to avoid soil disturbance. Plants were fertilized with muriate of potassium (a.i. K20, 60% K) at a rate of 600 g plant⁻¹ year⁻¹, split over 6 equal applications. Fertilizers applied included muriate of phosphorus (a.i. P2O5, 46% P) at a rate of 120 g plant⁻¹ year⁻¹ and Urea (47% N) at a rate of 300 g plant⁻¹ year⁻¹, split over 6 equal applications during the rainy season. No mulch was applied. The experimental area was treated with the nematicide Nemacur (a.i. triadimenol) was applied three times per year at a rate of 3.6 ml plant⁻¹ to control the leaf spot disease black sigatoka (Mycosphaerella fijiensis Morelet). Plants were irrigated during the dry season at a rate of 100 mm month⁻¹.

The field layout was a randomized complete block design with two replications of two plants per genotype. To avoid overlapping of adjacent root systems, plant spacing was 4 m x 4 m. The plants were completely excavated and the characteristics measured included plant height (PH, cm), number of leaves (NL), pseudostem circumference at soil level (PC, cm) and height of the tallest sucker (HS, cm). In addition, leaf area (LA, cm²) was calculated according to Obiefuna and Ndubizu (1979). Corm characteristics measured were fresh corm weight (CW, g), corm height (CH, cm) and widest width of the corm (WW, cm). The number of suckers (NS) on the corm were counted.

Root characteristics included the number of adventitious roots or cord roots (NR), root dry weight (DR, g) and the average basal diameter of the corm roots (AD, mm) measured with a Vernier Caliper. The corm root length (LR, cm) was measured using the line intersect method (Newman 1966, Tenant 1975). Other root system characteristics were total dry weight (TD, g) of the mat (i.e. plant crop and suckers) and total cord root length of the mat (TL, cm). Aerial growth, corm development and root system growth characteristics were also measured for the tallest sucker.

Statistical analysis was carried out using the SAS statistical package (SAS, 1989). Variability of the different growth characteristics was assessed using PROC GLM in SAS. Total pheno-

<table>
<thead>
<tr>
<th>Name</th>
<th>Genome</th>
<th>Ploidy level</th>
<th>Type</th>
<th>Suckering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyamira Yik</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata banksi</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Calcutta 4</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata burmannica</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Pahang</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata malaccensis</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Pisang J. Buaya</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata microcarpa</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Pisang Madu</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata microcarpa</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Tjau Lagada</td>
<td>AA</td>
<td>2</td>
<td>Musa acuminata microcarpa</td>
<td>Non regulated</td>
</tr>
<tr>
<td>Yangambi km5</td>
<td>AAA</td>
<td>3</td>
<td>Desert banana</td>
<td>Regulated</td>
</tr>
<tr>
<td>Valery</td>
<td>AAA</td>
<td>3</td>
<td>Plantain</td>
<td>Regulated</td>
</tr>
<tr>
<td>Obino l’Ewai</td>
<td>AAB</td>
<td>3</td>
<td>Plantain</td>
<td>Inhibited</td>
</tr>
<tr>
<td>Agbagba</td>
<td>AAB</td>
<td>3</td>
<td>Plantain</td>
<td>Inhibited</td>
</tr>
<tr>
<td>Pelipita</td>
<td>ABB</td>
<td>3</td>
<td>Cooking banana</td>
<td>Regulated</td>
</tr>
<tr>
<td>Cardaba</td>
<td>ABB</td>
<td>3</td>
<td>Cooking banana</td>
<td>Regulated</td>
</tr>
<tr>
<td>Fougamou</td>
<td>ABB</td>
<td>3</td>
<td>Cooking banana</td>
<td>Regulated</td>
</tr>
<tr>
<td>TMPx 2796-5</td>
<td>AAB x AA</td>
<td>4</td>
<td>Plantain hybrid (Bobby Tannap x Pisang lilin) illin</td>
<td>Regulated</td>
</tr>
<tr>
<td>TMPx 7152-2</td>
<td>AAB x AA</td>
<td>4</td>
<td>Plantain hybrid (Mbi Egome 1 x Calcutta 4)</td>
<td>Regulated</td>
</tr>
<tr>
<td>TMPx 548-9</td>
<td>AAB x AA</td>
<td>4</td>
<td>Plantain hybrid (Obino l’Ewai x Calcutta 4)</td>
<td>Regulated</td>
</tr>
<tr>
<td>TMPx 5511-2</td>
<td>AAB x AA</td>
<td>4</td>
<td>Plantain hybrid (Obino l’Ewai x Calcutta 4)</td>
<td>Inhibited</td>
</tr>
<tr>
<td>TMPx 1658-4</td>
<td>AAB x AA</td>
<td>4</td>
<td>Plantain hybrid (Obino l’Ewai x Pisang illin)</td>
<td>Regulated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Trait #</th>
<th>Source of variation</th>
<th>Trait #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td></td>
<td>Ploidy level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genome group</td>
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<td></td>
<td></td>
<td>Genotype</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residual</td>
<td></td>
</tr>
<tr>
<td>Replication</td>
<td></td>
<td>Ploidy level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genome group</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Genotype</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residual</td>
<td></td>
</tr>
<tr>
<td>Replication</td>
<td></td>
<td>Ploidy level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genome group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genotype</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residual</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mean square and significance tests of different quantitative traits of plants at flower emergence.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Source of variation</th>
<th>LA</th>
<th>PH</th>
<th>CW</th>
<th>NS</th>
<th>HS</th>
<th>DR</th>
<th>NR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Replication</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Ploidy level</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<td>Genotype</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>50</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* DF: degrees of freedom; LA: leaf area (m²); PH: plant height (cm); CW: corm weight (g); NS: number of suckers; HS: height of the tallest sucker (cm); DR: root dry weight (g); NR: number of cord roots; LR: cord root length (cm); AD: average basal cord root diameter (mm); TD: total root dry weight of the mat (g); TL: total length of the cord roots of the mat (cm); %MPDR: percentage root dry weight of the plant crop to the mat; %MPR: percentage cord root length of the plant crop to the mat; DTFL: days to flower emergence.

** Significant at P < 0.05, 0.01 and 0.001, respectively.

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Table 3. Musa spp. growth characteristics at flower emergence according to ploidy level.

<table>
<thead>
<tr>
<th>Trait#</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>92.635</td>
<td>± 6.617</td>
<td>78.968</td>
</tr>
<tr>
<td>NL</td>
<td>13</td>
<td>± 0.4</td>
<td>10</td>
</tr>
<tr>
<td>PH</td>
<td>228</td>
<td>± 8</td>
<td>248</td>
</tr>
<tr>
<td>PC</td>
<td>53</td>
<td>± 2</td>
<td>63</td>
</tr>
<tr>
<td>CW</td>
<td>4135</td>
<td>± 444</td>
<td>5312</td>
</tr>
<tr>
<td>CH</td>
<td>24</td>
<td>± 1</td>
<td>22</td>
</tr>
<tr>
<td>WW</td>
<td>16</td>
<td>± 1</td>
<td>20</td>
</tr>
<tr>
<td>NS</td>
<td>13</td>
<td>± 1</td>
<td>11</td>
</tr>
<tr>
<td>HS</td>
<td>161</td>
<td>± 15</td>
<td>141</td>
</tr>
<tr>
<td>DR</td>
<td>212</td>
<td>± 15</td>
<td>281</td>
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<td>NR</td>
<td>122</td>
<td>± 9</td>
<td>162</td>
</tr>
<tr>
<td>LR</td>
<td>5807</td>
<td>± 571</td>
<td>6136</td>
</tr>
<tr>
<td>AD</td>
<td>45.3</td>
<td>± 0.13</td>
<td>5.34</td>
</tr>
<tr>
<td>TD</td>
<td>533</td>
<td>± 59</td>
<td>513</td>
</tr>
<tr>
<td>TL</td>
<td>15236</td>
<td>± 2173</td>
<td>12468</td>
</tr>
<tr>
<td>% MPDR</td>
<td>45</td>
<td>± 3</td>
<td>56</td>
</tr>
<tr>
<td>% MFLR</td>
<td>46</td>
<td>± 3</td>
<td>53</td>
</tr>
<tr>
<td>DTFL</td>
<td>381</td>
<td>± 16</td>
<td>348</td>
</tr>
<tr>
<td>LADTL</td>
<td>242</td>
<td>± 14</td>
<td>237</td>
</tr>
<tr>
<td>PWDTFL</td>
<td>0.51</td>
<td>± 0.02</td>
<td>0.73</td>
</tr>
<tr>
<td>CWDTFL</td>
<td>11</td>
<td>± 1</td>
<td>16</td>
</tr>
<tr>
<td>HSODTL</td>
<td>0.44</td>
<td>± 0.04</td>
<td>0.41</td>
</tr>
<tr>
<td>DRDITL</td>
<td>0.56</td>
<td>± 0.04</td>
<td>0.84</td>
</tr>
<tr>
<td>NRDTFL</td>
<td>0.32</td>
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<td>± 1</td>
<td>18</td>
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<tr>
<td>TDTL</td>
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<td>1.50</td>
</tr>
<tr>
<td>TDTFL</td>
<td>39</td>
<td>± 5</td>
<td>36</td>
</tr>
</tbody>
</table>

#: see Table 1; NL: number of leaves; PC: pseudostem circumference (cm); CH: corm height (cm); WW: corm widest width (cm).

typic variance was partitioned according to the following sources of variation: replication, ploidy level, genome group and genotype.

Results and discussion
There was a significant effect of ploidy level on the different characteristics, except for root dry weight and cord root length of the mat (Table 2). Generally, with increasing ploidy level the magnitude of plant characteristics tends to increase. For example, the tetraploids had the highest values for leaf area, plant height, corm fresh weight, plant crop root traits and their respective daily growth rates (Table 3). The effect of genotype was significant for all assessed traits, while the effect of genome group was significant for all shoot and several root traits.

Simmonds (1962) reported also that fruit sizes increased with increasing ploidy levels, while Vandenhou et al. (1995) noted the same for the stomata size. Apparently the increased chromosome number resulted in larger cells causing an increase in the size of the plant organs. Vakili (1967) reported that colchicine derived tetraploids from M. balbisiana were taller and more robust but had slower growth rate, fewer suckers and scantier root systems than diploids. Contrary to these observations, higher daily growth rates and larger plant crop root systems were observed with increasing ploidy level in this study (Table 3). Cord root diameter increased with higher ploidy level (Table 3) confirming observations made by Monnet and Charpentier (1965).

There was an increase in sucker development with decreasing ploidy level. All diploid bananas had a non-regulating suckering behaviour (i.e. all suckers grow vigorously) resulting in a faster cycling, while the studied triploids and tetraploids had a regulated (i.e. 2 or 3 suckers grow vigorously) or an inhibited suckering (i.e. no sucker grows vigorously) (Table 1). For example, the plant crop accounted for only 45% of the root dry weight of the mat for the diploid banana indicating a strong sucker growth. Conversely, the plantains, the cooking bananas and the tetraploid plantain hybrids (AAAB) had higher values (Tables 3 and 4). The low values for shoot and root traits of the dessert banana group is probably due to the inclusion of the semi-dwarf variety ‘Valery’.

In this study, there was a tendency of increased shoot and root vigor for the higher ploidy levels. Conversely, sucker development and thus perennialization was enhanced with decreasing ploidy level.

Acknowledgements
Financial support by the Flemish Association for Development Cooperation and Technical Assistance (V.V.O.B.: Vlaamse Vereniging voor Ontwikkelings SAMENWERKING EN TECHNISCHE BIJSTAND) and the Directorate General for International Cooperation (DGIC, Belgium) is gratefully acknowledged. The authors thank Miss Lynda Onyeukwu for helping with the data collection.

References
Table 4. Musa growth characteristics at flower emergence for the triploid genome groups

<table>
<thead>
<tr>
<th>Trait #</th>
<th>AAA</th>
<th>AAB</th>
<th>ABB</th>
</tr>
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<tbody>
<tr>
<td>LA</td>
<td>58 208 ± 9 730</td>
<td>92 365 ± 5 888</td>
<td>85 513 ± 7 710</td>
</tr>
<tr>
<td>NL</td>
<td>± 1</td>
<td>± 0.5</td>
<td>± 0.9</td>
</tr>
<tr>
<td>PH</td>
<td>215 ± 11</td>
<td>257 ± 8</td>
<td>268 ± 8</td>
</tr>
<tr>
<td>PC</td>
<td>55 ± 2</td>
<td>62 ± 1</td>
<td>69 ± 2</td>
</tr>
<tr>
<td>CW</td>
<td>3 945 ± 354</td>
<td>6 285 ± 290</td>
<td>5 662 ± 369</td>
</tr>
<tr>
<td>CH</td>
<td>23 ± 2</td>
<td>22 ± 1</td>
<td>22 ± 1</td>
</tr>
<tr>
<td>VV</td>
<td>17 ± 1</td>
<td>22 ± 1</td>
<td>20 ± 1</td>
</tr>
<tr>
<td>NS</td>
<td>14 ± 1</td>
<td>13 ± 1</td>
<td>8 ± 1</td>
</tr>
<tr>
<td>HS</td>
<td>165 ± 23</td>
<td>106 ± 10</td>
<td>150 ± 22</td>
</tr>
<tr>
<td>DR</td>
<td>220 ± 30</td>
<td>254 ± 31</td>
<td>361 ± 39</td>
</tr>
<tr>
<td>NR</td>
<td>135 ± 10</td>
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<td>195 ± 16</td>
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<td>5 285 ± 793</td>
<td>6 465 ± 397</td>
<td>6 599 ± 618</td>
</tr>
<tr>
<td>AD</td>
<td>4.9 ± 0.1</td>
<td>5.8 ± 0.2</td>
<td>5.3 ± 0.1</td>
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<tr>
<td>TD</td>
<td>556 ± 81</td>
<td>409 ± 18</td>
<td>567 ± 45</td>
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<tr>
<td>TL</td>
<td>14 883 ± 2 647</td>
<td>11 278 ± 1 358</td>
<td>11 379 ± 1 266</td>
</tr>
<tr>
<td>% MPDR</td>
<td>43 ± 5</td>
<td>62 ± 7</td>
<td>64 ± 4</td>
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<tr>
<td>% MPLR</td>
<td>36 ± 5</td>
<td>61 ± 5</td>
<td>60 ± 5</td>
</tr>
<tr>
<td>DTLTL</td>
<td>368 ± 24</td>
<td>338 ± 9</td>
<td>340 ± 25</td>
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<tr>
<td>LA/DTTL</td>
<td>168 ± 35</td>
<td>276 ± 20</td>
<td>264 ± 32</td>
</tr>
<tr>
<td>PH/DTTL</td>
<td>0.61 ± 0.06</td>
<td>0.77 ± 0.04</td>
<td>0.82 ± 0.06</td>
</tr>
<tr>
<td>CW/DTTL</td>
<td>1 ± 1</td>
<td>19 ± 1</td>
<td>17 ± 2</td>
</tr>
<tr>
<td>HS/DTTL</td>
<td>0.45 ± 0.06</td>
<td>0.32 ± 0.03</td>
<td>0.46 ± 0.07</td>
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<tr>
<td>DR/DTTL</td>
<td>0.60 ± 0.07</td>
<td>0.77 ± 0.11</td>
<td>1.13 ± 0.15</td>
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<tr>
<td>NR/DTTL</td>
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<td>0.45 ± 0.03</td>
<td>0.61 ± 0.08</td>
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<tr>
<td>LR/DTTL</td>
<td>15 ± 2</td>
<td>19 ± 1</td>
<td>20 ± 2</td>
</tr>
<tr>
<td>TD/DTTL</td>
<td>1.50 ± 0.19</td>
<td>1.21 ± 0.05</td>
<td>1.75 ± 0.17</td>
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<td>TL/DTTL</td>
<td>40 ± 7</td>
<td>33 ± 3</td>
<td>34 ± 3</td>
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</table>

# see Tables 2 and 3.
Use of a new biological nematicide to protect the roots of plantain (Musa AAB) multiplied by micropropagation

Lazaró L. Castellanos Lopez, Jorge Lopez Torrez, Julian Gonzalez Rodríguez. Sergio Rodríguez Morales and José De La C. Ventura Martín

The cultivation of bananas and plantains represents substantial food and economic resources for a large proportion of the world’s population, mainly in the developing countries in Asia, Africa and Latin America. Although conventional propagation methods are still used in many of these countries, micropropagation has gained popularity in recent years as an innovative alternative in multiplication. Indeed, in vitro culture makes it possible to produce disease and pest-free plants for transfer to the field. However, the plants are still very delicate at transplantation, making them susceptible to plant parasitic nematodes, which sometimes cause considerable yield losses, as in the case of Melodydogine spp. These losses can be almost completely eliminated if the soil is disinfected before planting or if planting is performed in nematode-free soil. However, this is not very easy to achieve. On the one hand, the application of chemical nematicides considerably affects the production process and destroys the ecological balance of the soil, and on the other hand the methods for the detection of nematodes in the soil are not totally reliable. Nematodes are practically impossible to detect when the soil pest population is very small. As a result, farmers may be inclined to use infested land that appears to be completely free of nematodes and considered unworthy of nematicide application. However, as months go by, it will be seen that nematode populations are indeed present and that the defenseless roots of the plantlets are either practically non-existent or are covered with thick nodules.

The use of nematode-trapping fungi belonging to different genera such as Harposporium sp., Dactylella spp., Stylopage sp., Dactylaria spp., Catenaria sp. and Arthrobotrys sp. (Dudington 1956, Cortado 1968, Genalaao 1986, Stirling 1988, Persson 1997) appears to be a promising alternative for addressing this problem. These organisms have several kinds of advantage in the biological control of nematodes, including:

• their ability to trap and eliminate a large number of nematode species using specialized capture structures or organs to trap moving parasites (loops, contractile or not; nets; sticky structures and other methods). This is a particularly interesting feature as control is thus performed before the nematode penetrates the root and causes damage there;

• their ability to produce substances that attract the parasites; this further increases their control effectiveness with regard to the latter;

• some of these fungi release a large quantity of resistance spores, making it possible to formulate them in different ways.

INIVIT maintains a stock of nematophagous and/or nematode parasite fungi isolated from Cuban soils planted with banana and plantain. Many have already been characterized and have displayed considerable pathogenicity with regard to the main nematode species infecting Cuban banana crops.

The introduction of nematophagous fungi in the rhizosphere of tissue culture plants would make it possible to reduce or eliminate production losses, to reduce the costs involved in the use of chemicals and to conserve soils, since the protection of the roots of plantlets would be achieved in a natural and ecological manner. This was the reason for undertaking research on the strain INIVIT 99-1 TPB of Arthrobotrys sp. with regard to protection of the roots of CEMSA 3/4 plantain (Musa AAB) multiplied by micropropagation.

Material and methods

The research was conducted at INIVIT in the tissue culture plant weaning zone in 1999.

In vitro plants of the CEMSA 3/4 plantain clone (Musa spp. AAB) were used and the work concerned only the adaptation phase. The treatments are listed as A = control, B = biological nematicide + Radopholus similis inoculum, C = R. similis inoculum and D = biological nematicide only.

Micropropagated plants ready for weaning were used. They were planted in pots containing sterilized substrate
prepared from red soil, compost and bagasse. Ten days after planting, treatments B and D were inoculated with nematicide. After five days, each pot of treatments B and C received a suspension of 5 x 103 nematodes (R. similis) prepared by tissue culture on slices of carrot (Daucus carota). The percentage of root infection, total weight, root weight and the height of each tissue culture plant were measured 60 days later.

Results and discussion

Unlike treatment C, treatments B and D did not display significant differences with regard to the control treatment A for all the parameters evaluated (Figure 1). This shows that when biological control is present, R. similis does not cause serious damage to in vitro plant roots. These results confirm those reported for other biological nematicides (Jatala 1986, Davide 1994) used to protect the roots of other crops.

The plants to which the nematicide had only been applied displayed greater height and weight than those of the other treatments; significant differences were very small for the control and treatment B but high for treatment C (Table 1).

The greater height and root weight of the in vitro plants on which the strain INIVIT 99-1 TPB was introduced may result from the fact that this organism contributes to the decomposition of organic matter and releases nutrients into the soil that can then be taken up by the in vitro plants, which is not the case in the treatments not including microorganisms. It is also possible that the organisms produce substances that stimulate plant growth, as occurs in other soil microorganisms (Davide 1994).

Conclusions and recommendations

The use of biological nematicide (Cepa INIVIT 99-1 TPB de Arthrobotrys sp.) effectively protects the roots of CEMSA 3/4 plantain in vitro plants from attack by R. similis.

When it is used during the adaptation phase, INIVIT 99-1 TPB combined with compost and bagasse increases the height and weight of CEMSA 3/4 tissue culture plants.

Use of the new biological nematicide INIVIT 99-1 TPB is recommended for the protection of the roots of plantain in vitro plants.

It is recommended that the efficacy of the nematicide should be tested on other banana and plantain clones susceptible to plant nematode attacks.

It is recommended that the efficacy of the nematicide should be tested on other nematode species of great economic importance, such as Meloidogyne spp., Pratylenchus coffeeae and Helicotylenchus multicinctus.

References


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<table>
<thead>
<tr>
<th>Table 1. Effect of the different treatments on the root weight of plantain tissue culture.</th>
</tr>
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<tbody>
<tr>
<td>Treatment</td>
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<td>Root weight (g.)</td>
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<td>The values followed by the same letter are significantly different at P &lt; 0.05.</td>
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</table>

Edna A. Aguilar, David W. Turner and K. Sivasithamparam

Proposed mechanisms on how Cavendish bananas are predisposed to Fusarium wilt during hypoxia

Localized wilting in Cavendish plants in the Philippines (Stover 1990) and Carnarvon, Western Australia (Pegg et al. 1995) have been associated with sub-optimal conditions such as waterlogging and poor drainage. These anecdotal reports have not been investigated experimentally.

Excess water can be a problem in banana plantations, particularly after a heavy rainfall or irrigation of heavy soil. Banana fields may suffer flooding or long-term waterlogging that may damage the root system and contribute to the susceptibility of bananas to Fusarium wilt (FW).

Waterlogging reduces O2 and increases CO2 and ethylene concentration in soil (Ponnampерuma 1984). The diffusivity of O2 in water is 1/10 000th of its value in air; thus, dissolved O2 in the soil solution is depleted in a few hours or days due to consumption by plant roots and soil microorganisms (Drew 1990). O2 is essential for respiration, the process by which aerobic organisms produce energy in the form of ATP. Here, we review recent studies on the short-term response of banana roots and the FW pathogen (Fusarium oxysporum f.sp. cubense (E.F. Smith) Snyder and Hansen) to O2 deficiency and suggest a role for these responses in the

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predisposition of putative resistant banana cultivars to FW.

Possible role of aerenchyma

Lysigenous air spaces (aerenchyma) have been reported in earlier studies of banana roots and in a number of cultivars (Acquarone 1930, Riopel & Steeves 1964, Aguilar et al. 1999). The aerenchyma provides a continuous path for O₂ diffusion from shoots to roots, increasing the flux of O₂ along the cortex. We quantified the root porosity of different banana cultivars and measured inherent differences in ease of O₂ movement along roots. The mature roots of Cavendish cultivars (AAA) have 10% of the volume as aerenchyma while Goldfinger (AAAB) has 5% (Aguilar et al. 1999). Hypoxia further increased porosity and the thickness of the roots (Figure 1). When the physical resistance to internal gas diffusion was compared, the differences between the four cultivars studied disappeared (Aguilar et al. 1998), suggesting that these roots were equally adapted to stagnant conditions and potentially conduct gaseous O₂ three to five times more easily than aerated roots. O₂ concentration in the root tissues is sensitive to changes in the outside O₂ concentration. Even with cortical aerenchyma, the stele, where the pathogen initiates the disease, has low O₂ concentrations (1.3-2.6 kPa) even if the medium outside of the root is fully aerated (21 kPa) (Aguilar et al. 1998) (Figure 2). Hypoxia (4 kPa O₂) outside the roots induces stelar anoxia in excised banana roots (Aguilar 1998). Reducing the O₂ concentration at the root surface to about 18 kPa is estimated to already create an anoxic core in the stele. This finding has implications for the development of Fusarium wilt because it is in the stele where the host and pathogen interaction is critical in disease development. When the stele is anoxic, the mobilization of the host defense mechanisms in infected roots may be slowed or stopped altogether, since most of these processes require energy.

If the FW pathogen could better tolerate lower O₂ concentrations, it would have the impetus to colonize and be systemically distributed along the roots while the root suffers. In in vitro studies, mycelial growth remained unimpaired even at 1% O₂ but no growth occurred under anoxia (0% O₂). Regeneration of growth following return of aeration was observed (Aguilar 1998). Germinating Foc conidia had low hyphal density and frequently ceased activity and produced chlamydospores or resting hyphae when O₂ becomes limiting (Figure 3). Our studies further showed that the pathogen could exploit the presence of aerenchyma and the associated higher concentrations of O₂ it contains (Aguilar 1998) (Figure 4).

Thus, the aerenchyma, although providing an advantage for the host to survive hypoxic conditions, could be the “Achilles heel” of some banana cultivars that could otherwise resist Fusarium wilt. Aerenchyma appears to offer an alternative and favourable path for the pathogen to invade the root longitudinally, outside of the vascular system. It is possible to envisage a scenario where the pathogen, using the aerenchyma as a base, occasionally grows into the stele, to access nutrients, then transfers them via cytoplasmic streaming back to the mycelium in the aerenchyma where it obtains its respiratory requirement. This situation enables the pathogen to continue its growth in the stele that by itself would be an adverse environment. It is likely that when conditions in the stele are inhospitable for the pathogen, Foc could resort to a latent phase. The process involving the passage of the pathogen through the aerenchyma could contribute to rapid invasion of the corm (Aguilar 1998).

Role of reduced root elongation and root tip death under anoxia

Anoxia (0% O₂) in the root medium stopped root elongation within 30 minutes. Re-aeration after 4 h of anoxia restored elongation rate to only 50% of...
Fusarium oxysporum f. sp. 

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ity in a host resistant interaction. The best option for the host to incur resistance would be to sufficiently increase enzyme activities during hypoxia to contain the then inactive pathogen before re-aeration. Post-anoxic injury when the stress becomes too severe, could deprive the host of its ability for continued resistance (Aguilar et al. 2000).

Conclusion
It is the physiological state of the host upon re-aeration that will determine the outcome of host-pathogen interaction under oxygen deficiency. Irreparable damage to root function would surely favour the pathogen, and hence, disease development follows or may even be enhanced. If the root acclimates and elicits timely and sufficient defence reactions during hypoxia, then it could gain advantage over the pathogen. When the next stress occurs, its duration and severity will most likely determine the ensuing host-pathogen dynamics (Aguilar 1998).

References

Figure 5. Root elongation of banana cv. Williams in aerated nutrient solution (control) and after imposition of 2.4 and 6.5 hours of anoxia.

Figure 6. Effect of inoculation by Fusarium oxysporum f.sp. cubense (Foc) and hypoxia on phenylalanine ammonia-lyase (PAL) enzyme activity in roots of banana cvs a) Williams, b) Goldfinger, c) Gros Michel and d) Sugar. Treatments were: no Foc, continuously aerated (NFA); Foc-inoculated, continuously aerated (FA); Foc-inoculated, continuously hypoxic (NFH); no Foc, hypoxic for 48 h, then re-aerated (NFHA); and Foc-inoculated, hypoxic for 48 h, then re-aerated (FHA). Vertical bars along line plots are standard errors where they are larger than the symbols. Vertical lines outside of plots are measures of significant mean differences at p = 0.05 using Duncan’s Multiple Range Test (DMRT). Top to first division is for comparison of adjacent points, while from the top to the bottom division is for comparison of highest to lowest points.

Figure 7. Effect of inoculation by Fusarium oxysporum f.sp. cubense (Foc) and hypoxia on peroxidase (PER) enzyme activity in roots of banana cvs a) Williams, b) Goldfinger, c) Gros Michel and d) Sugar. Treatments were: no Foc, continuously aerated (NFA); Foc-inoculated, continuously aerated (FA); Foc-inoculated, continuously hypoxic (FHH); no Foc, hypoxic for 48 h, then re-aerated (NFHA); and Foc-inoculated, hypoxic for 48 h, then re-aerated (FHA). Vertical bars along line plots are standard errors where they are larger than the symbols. Vertical lines outside of plots are measures of significant mean differences at p = 0.05 using Duncan’s Multiple Range Test (DMRT). From top to first division is for comparison of adjacent points, while from the top to the bottom division is for comparison of highest to lowest points. Horizontal line HH indicates the duration of the continuous hypoxic treatment (120 h total) and HA indicates the duration of the short-term hypoxia (48 h) and when re-aeration commenced (72 h).
ploid banana (Musa acuminata Colla). Euphytica 75: 121-129.


Soil chemical parameters in relation to the incidence and intensity of Panama disease

Josué Francisco da Silva Junior, Zilton José Maciel Cordeiro and Arlene Maria Gomes Oliveira

Panama disease or Fusarium wilt of banana caused by the fungus Fusarium oxysporum f. sp. cubense (Foc) is one of the most serious problems in banana production as it causes serious damage in outbreak zones. The decisive role played by the genotype of banana cultivars in the expression of their resistance or susceptibility to the disease is well known. However, it is also considered that the intensity of Panama disease is more or less directly related to edaphic factors and plant nutrition and that these features may affect resistance mechanisms such as gel (gum) formation and tylosis (Stover 1962, Borges Perez et al. 1983, Beckman 1990).

In the Canary Islands, Alvarez et al. (1981), Gutierrez Jerez et al. (1983), Borges Perez et al. (1983) and Trujillo J acinto del Castillo et al. (1983) performed soil observations in healthy and infected zones and concluded that the pH, the organic matter content (OM), levels of calcium (Ca), magnesium (Mg) and zinc (Zn) and Ca:Mg and K:Mg ratios were closely correlated with the appearance of the disease. In Taiwan, Tu and Cheng (1982), Hwang (1985), Sun and Huang (1985) and Su et al. (1986) obtained promising results when they undertook tests with a view to controlling Panama disease by means of suppressive and conducive soils and the addition of various organic or inorganic compounds to soils where there had been severe attacks of the disease. Observations in Bahia State in Brazil showed that the organic matter content was higher in healthy soil zones (EMBRAPA 1987).

In Brazil again, Malburg et al. (1984) reported that low pH values and Ca, Mg and Zn levels in soils in Santa Catarina State planted with ‘Enxerto’ (‘Prata Anã’ AAB) and ‘Branca’ (AAB) bananas were related to a high wilt level. Observations in Bahia and Espirito Santo showed that in infected zones the pH and Ca, Mg and Zn levels were low whereas K:Ca and K:Mg ratios were high (EMBRAPA 1987, EMCAPA 1988).

In the Canaries and in Brazil, the addition of Mg, Zn and Ca through ZnSO₄ or CaSO₄.2H₂O significantly reduced the incidence of Panama disease in ‘Dwarf Cavendish’ banana.

In the light of these results, the work presented here aimed at evaluating the effect of chemical characteristics of soils such as the organic matter content, pH, level and Ca, Mg and Zn levels on the incidence and intensity of Panama disease in ‘Prata Anã’ banana (AAB).

Material and methods

The trial was performed on land belonging to the Centro Nacional de Pesquisa de Mandioca e Fruticultura Tropical (CNPMF), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), at Cruz das Almas, Bahia State, Brazil. Holes with a volume of 0.38 m³ (0.70 m in diameter and 0.30 m deep) lined with polyethylene were filled with either yellow latosol with cohesion Tb, and medium to clayey texture or with organic soil collected at a depth of 0 to 30 cm. The original chemical characteristics of the soils used are shown in Table 1. Corms weighing about 2 kg of the cultivar ‘Prata Anã’ (AAB), considered to be susceptible to Panama disease (Cordeiro et al. 1991), were planted.

A fully random statistical protocol was used with 10 treatments and 10 repetitions, with each plant representing an experimental plot. The following treatments were applied to evaluate the effect of Ca alone or in combination with Mg, pH, OM or soil sterilization and the addition of Zn: 0) Organic soil + liming 1) Sterilized organic soil + liming 2) Sterilized inorganic soil + liming 3) Inorganic soil with no liming 4) Inorganic soil + ZnSO₄ + liming 5) Inorganic soil + ZnO + liming 6) Inorganic soil + Zn + liming 7) Inorganic soil + liming with CaCO₃ (pH approximately 7.5) 8) Inorganic soil + liming with CaCO₃ and MgO (pH approximately 7.5) 9) Inorganic soil + CaCO₃ + MgO (pH approximately 7.5)
Dolimitic limestone (total relative neutralization capacity 99%) was used in treatments 1, 2, 3, 5 and 6 to achieve Ca+Mg contents of 40 mmol/dm³ in conformity with the indications provided by the soil analysis (Comissão Estadual de Fertilidade do Solo 1989). This means that 3.13 t/ha lime was added in treatments 1 and 2 and 2.93 t/ha to treatments 3, 5 and 6. Treatment 4 was the control since it does not include any liming.

In treatments 7, 8 and 9, the Ca and Mg sources (calcitic lime, dolomitic lime and magnesium oxide respectively) raised the soil pH to approximately 7.5. In conformity with the incubation method recommendations, 9.48 t/ha calcitic lime was added in treatment 7, while 7.46 t/ha dolomitic lime was added in treatment 8, and 3.23 t/ha magnesium oxide in treatment 9.

In treatment 10, application of 13.70 t/ha agricultural plaster corresponded to 277.12 g Ca per hole, i.e. the same amount Ca as applied in treatment 7 in the form of CaCO₃.

Zinc sulphate at 19.05 g/hole, the equivalent of 4.0 g Zn/plant was added two months after sowing in treatment 5 at the same time as the first nitrogen fertilization.

The plants were fertilized with NPK at 100 kg N/ha, 40 kg P₂O₅/ha and 450 kg K₂O/ha, provided by ammonium sulphate, single superphosphate and potassium chloride respectively.

Soils were analyzed using the methodology of the Serviço Nacional de Levantamento e Conservação de Solos - SNLCS - EMBRAPA (1979). Samples were taken during the following phases of the experiment: before the holes were dug, at planting (two months after chemical correction) and after 11 months of plant growth.

The plantlets were inoculated four months after planting with 6.0 ml suspension of Foc spores, corresponding to 8.3 x 10⁵ conidia/hole or 700 conidia/g soil. The inoculum was placed in 100g maize flour-sand mixture. Inoculation was performed by digging furrows 10 cm deep around each plant, spreading the inoculum and then refilling immediately (EMBRAPA 1991).

The final evaluation of infection was performed seven months after inoculation by pulling out 11-month-old plants to observe the degree of rhizome infection in a series of cross sections running from the base to the apex and recording scores of 0 to 6 on the scale proposed by Cordeiro et al. (1993):

- 0: Rhizome totally undamaged
- 1: Isolated points of infection
- 2: Infection covering more than 1/3 of the stele cross section
- 3: Infection covering 1/3 to 2/3 of the stele cross section
- 4: More than 2/3 of the stele cross section infected
- 5: Overall infection
- 6: A plant displaying external symptoms and/or symptoms visible on the pseudostem

Analysis was performed from the data obtained by applying Tukey’s test (P < 0.05) to compare the averages of the different treatments. Pearce’s correlation coefficients were also calculated.

**Results and discussion**

**The effect of organic matter**
The high OM content of the organic soil in comparison with that of the inorganic soil affects the levels of intensity of the disease. Indeed, treatments 1 and 2 display lower indices of infection than those of the other treatments (Figure 1). The strong correlation (r = 0.61) between the average score for Foc infection and the organic matter content (Table 2) confirms the positive effect of OM on the control of Foc, with a 1% degree of significance. In addition, with no sterilization (treatment 1), the use of organic soil results in significant differences compared to the control (treatment 4) in Tukey's test (5%).

These results show that the damage to plants caused by the pathogen is insignificant, implying that this soil may possess a suppressive character that remains as long as the conditions determining it are maintained. According to Hornby (1983), the majority of the mechanisms proposed for explaining the suppression of the disease on this type of soil have not been proved. It is assumed that abiotic factors such as climate, soil chemical characteristics (acidity, type of clay) and physical characteristics (moisture) act in synergy with the biotic factors.

Among biotic factors, it is supposed that the phenomenon of antagonism between the original soil microbiosphere and the pathogen causes the reduction of infection. The phenomenon is very common in soils that are very rich in OM and is important for the microbiological equilibrium of the soil and the biological control of pathogenic organisms (Clark 1965, Siqueira and Franco 1988). The high percentage of OM is generally related to a high microbial population (Warcup 1965) and increases the soil fungistasis effect, making it difficult for a newly introduced microorganism to become established. This results in reduction or control of the disease.

There are no significant differences between infection levels with regard to the sterilization or not of organic soils (treatments 1 and 2) and mineral soils (treatments 3 and 6) (Figure 1). According to Hemwall (1960), soils with a high OM content are relatively difficult to fumigate. Later, Kreutzer (1965) pointed out that OM can also protect soil microorganisms from the effect of fumigants.

In addition, it is known that when soils are sterilized, as in this experiment, the original microbiosphere recov-

### Table 1. Initial chemical characteristics of the yellow latosol and the organic soil (from a depth of 0-30 cm) used in the trial at Cruz das Almas, BA, Brazil.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Yellow latosol</th>
<th>Organic soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH-H₂O</td>
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<td>4.70</td>
</tr>
<tr>
<td>P (mg/dm³)</td>
<td>0.90</td>
<td>27.50</td>
</tr>
<tr>
<td>K (mmol/dm³)</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td>Ca (mmol/dm³)</td>
<td>6.50</td>
<td>6.50</td>
</tr>
<tr>
<td>Mg (mmol/dm³)</td>
<td>4.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Al (mmol/dm³)</td>
<td>1.00</td>
<td>1.20</td>
</tr>
<tr>
<td>Na (mmol/dm³)</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td>H + Al (mmol/dm³)</td>
<td>54.00</td>
<td>188.00</td>
</tr>
<tr>
<td>CTC (mmol/dm³)</td>
<td>66.00</td>
<td>198.00</td>
</tr>
<tr>
<td>Organic matter (g/dm³)</td>
<td>21.00</td>
<td>173.00</td>
</tr>
<tr>
<td>Mn (mg/dm³)</td>
<td>3.94</td>
<td>1.10</td>
</tr>
<tr>
<td>Fe (mg/dm³)</td>
<td>89.05</td>
<td>27.49</td>
</tr>
<tr>
<td>Zn (mg/dm³)</td>
<td>3.50</td>
<td>3.17</td>
</tr>
<tr>
<td>Cu (mg/dm³)</td>
<td>0.31</td>
<td>0.71</td>
</tr>
</tbody>
</table>

### Table 2. Coefficients of correlation between organic matter, pH and Foc infection scores.

<table>
<thead>
<tr>
<th>Variables</th>
<th>pH</th>
<th>Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter</td>
<td>-0.22*</td>
<td>-0.61**</td>
</tr>
<tr>
<td>Infection score</td>
<td>0.43**</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.05 probability.
** Significant at 0.01 probability.
ers rapidly because methyl bromide does not have any residual effects (Kreutzer 1965, Vanachtert 1979). Some microorganisms that possess survival structures and resist fumigation— in particular certain fungi— may be capable of initiating repopulation (Kreutzer 1965).

The effect of pH, calcium and magnesium

The application of large quantities of Ca alone, using agricultural plaster, without changing the initial pH of inorganic soil (treatment 10), did not have a positive effect on the control of the disease (Figure 1). This is in conformity with the experiments performed by Knudson from 1923 to 1927 (Stover 1962), in which the Ca compounds used did not modify the soil pH.

It is observed that the high soil pH results in an infection rate that is also high. The liming performed to raise the pH to approximately 7.5 in treatments 7, 8 and 9 using large quantities of Ca, Ca+Mg, and Mg respectively did not have a positive effect with regard to control of Panama disease, since the infection levels observed were higher than that of the control (Figure 1).

Similar results were obtained in some production regions in the world (Stover 1962, Blesa Rodríguez and Fernández Caldas 1973, García 1977) where soils with high pH and high Ca and Mg contents were affected by the disease. There have been even cases, as in Taiwan (Hwang 1985), in which the highest infection indexes were recorded in zones where liming was performed (zones with a pH higher than 7.0). However, the positive effect on Panama disease of a high pH combined with Ca and Mg has been widely described in the literature, with the observations and tests performed by Knudson (1923-1927), Volk (1930 a, b), Volk and Gallatin (1930), Wardlaw (1935), quoted by Stover (1962), Scarseth (1945), Rishbeth (1957), Stover and Malo (1972), Alvarez et al. (1981), Malburg et al. (1984) and EMCAPA (1988).

In treatments 7, 8 and 9, the large doses of Ca and Mg applied singly or together, combined with a high pH probably caused an imbalance in the inorganic soil, influencing not only its chemical characteristics but also its original microbiosphere, in which microorganisms that are important competition for the pathogen were thus eliminated. This imbalance, combined with the susceptibility of the cultivar used, may have contributed to higher levels of infection in the plants.

In treatment 4 (Figure 1), the balance soil characteristics was almost unchanged and this may be one of the reasons for the minor incidence of the disease. In addition to this, the poor soil fertility conditions in this treatment may have caused less root growth resulting in a smaller infection index because the pathogen penetrates the plants via the secondary and tertiary roots (Stover 1962). The more developed the root system, the greater the chances of new infections.

The effect of zinc

There were no significant differences in infection levels when zinc was added to inorganic soil (treatment 5) and compared with treatments 4 (control) and 6 (treatment without Zn but with liming) (Figure 1). Because of its susceptible behaviour, the cultivar ‘Prata Anã’ is probably not effective in time and space in the development of effective resistance mechanisms (Beckman et al. 1962, Borges Perez et al. 1983, Beckman 1990). Or perhaps it might have been necessary to add larger quantities of this nutrient, as is done on ‘Dwarf Cavendish’ in the Canary Islands (Borges Perez et al. 1991). A third hypothesis could be that Zn has little or no effect on the control of Panama disease in contrast with suppositions.

Conclusions

Organic soil was found to be a suppressive substrate for the development of Panama disease in ‘Prata Anã’ banana.

Liming performed to raise the soil pH to approximately 7.5 using Ca and Mg and the addition of large quantities of Ca alone without modifying the soil pH have no positive effect on the control of Panama disease.

Acknowledgements

The authors thank Ana Lucia Borges and Aristóteles Pires de Matos, researchers at Embrapa Mandioca e Fruticultura, for their suggestions.

References


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Claudia Milena Cardona Torres, Gustavo Adolfo Yepes González and Jairo Castaño Zapata

**Mutation breeding using 60Co**

**Intensity of black Sigatoka (Mycosphaerella fijiensis Morelet) and yellow Sigatoka (Mycosphaerella musicola Leach) in Musa AAB cv. ’Dominico Hartón’ subjected to irradiation by 60Co**

The Musa industry (banana and plantain) is one of the farming activities with the greatest social impact in the regions where it is practised. Black Sigatoka disease (caused by Mycosphaerella fijiensis) is the main phytosanitary threat to these food and income resources (Jacome 1998). Yellow Sigatoka disease (caused by M. musicola) is gradually being replaced by black Sigatoka in large cultivated areas. The latter disease can cause a decrease in harvest of up to 50 percent, affecting growers’ incomes considerably (Burt et al. 1997). According to the most recent epidemiological observations, black Sigatoka can affect crops from sea level to an elevation of 1940 m. It was believed possible that only small outbreaks would occur higher than 1000 m but observations in Colombia have shown that this is not the case (Aguirre et al. 1998).

Chemical control and breeding resistant plants are still the only strategies for controlling black Sigatoka. Cultivars with some degree of genetic tolerance might not seem to be a priority for large growers whereas for small farmers resistance or tolerant or resistant clones are the control method best-suited to the technical training and socioeconomic context of the crop (Wesseling et al. 1996, quoted by Riveros and Lepoiivre 1998).

The main aim of the research work presented here was to evaluate the effect of mutagenesis caused by 60Co on the type of resistance or tolerance that could be developed by the cultivar ‘Dominico Hartón’ with regard to black Sigatoka (M. fijiensis) or yellow Sigatoka (M. musicola).

**Material and methods**

The project was set up at the Campoalegre plantation on the La Ceiba track on the Manizales (Caldas) – Mariquita road 7 km from Fresno in Tolima department at an elevation of 1250 m, with an average temperature of 18 to 25°C, relative humidity of 65 to 100% and annual precipitation of 1800 mm. The land is sloping and black and yellow Sigatoka had been detected. Planting was performed with 1600 ’Dominico Hartón’ tissue culture plants that had been subjected to 60Co at a dose of 25
The amendments produced in the cultural laboratory, weaned at Granja Montelindo, owned by Universidad de Caldas, and finally transported to the planting location. The plants produced by mutagenesis were surrounded by non-irradiated plants of the same clone (controls) to obtain greater inoculum pressure. Evaluations were performed each week from 24 May 1998 to 10 April 1999 on 58 cloned plants and 5 control plants. Each cloned plant was considered as an experimental unit for the following variables:

**Host parameters:** number of functional leaves on the pseudostem, date of shooting of the inflorescence and bunch weight (kg).

**Disease parameters:** youngest leaf spotted (YLS), taking into consideration stage 4 spots for yellow Sigatoka and stage 5 spots for black Sigatoka, intensity of disease attacks according to Stover's scale modified by Gauhl (1984) and the infection index of the diseases. Intensity scale of yellow and black Sigatoka diseases:

0. Healthy leaf, no symptoms
1. Up to 5% of leaf affected
2. 6 to 15% of leaf affected
3. 16 to 33% of leaf affected
4. 34 to 50% of leaf affected
5. 51 to 100% of leaf affected

**Intended scale:** calculated using the formula of Townsend and Heuberguer according to Unterstenhuefer (1963), quoted by Orjeda et al. (1998):

\[
IS = \frac{\sum bx}{(N-1)T} \times 100
\]

in which:

- \(b\) = number of leaves at each stage
- \(n\) = number of stages used in the scale
- \(T\) = total number of leaves evaluated

**Index of the youngest spotted leaf:** calculated using the following formula:

\[
I_{YLS} = \frac{T \times (YLS - 1)}{T} \times 100
\]

in which:

- \(T\) = total number of leaves evaluated
- \(YLS\) = youngest leaf spotted
- \(I_{YLS}\) = index of the youngest leaf spotted

**Meteorological parameters:** temperature (maximum, minimum and average), relative humidity and precipitation. The climatic conditions in the study zone consisted of an average temperature of 21.5°C, relative humidity of 81% and cumulated precipitation of 340.5 mm. Analysis of the climatic conditions in detail and in relation to the development of the diseases showed that precipitation is a determinant parameter for the appearance of infection. Temperature and relative humidity during the study enhanced the development of the epidemic as temperatures of 20 to 35°C enable ascospore and conidium germination; this is maximized at temperatures of the order of 25 to 28°C with high relative humidity and wet leaves (Jacome and Schuh 1992). The diseases display seasonal dynamics determined by variations in temperature and precipitation throughout the year, because the reproductive structures develop by cross-inoculation, a process enhanced by the presence of moisture on the leaves (Mourichon and Zapater 1990).

The development curve of the diseases displays two peaks on the 297th and 477th day after planting. These dates coincide with periods of strong precipitation (Figure 1). The crop was still in the vegetative phase 297 days after planting, but very close to the flowering period, hence the importance of keeping a large number of leaves. Indeed, as reported by Ortiz and Vuylsteke (1994), quoted by Craenen (1998), a minimum of eight functional leaves are required throughout the cycle to achieve a good yield. In addition, plants with fewer than eight non-spotted leaves before flowering are listed as being susceptible to black Sigatoka disease. The cloned plants were at the bunch development stage 477 days after planting. This is why a better bunch weight was not attained at the end of the experiment, because in 80% of the specimens evaluated the youngest leaf spotted (YLS) was in position 1 with high disease intensity indexes of up to 100%.

Only 45% of the clones evaluated, including the controls, reached the flowering stage with more than eight functional leaves. Among them, clones 4, 17, 18, 21, 38 and 44 stood out as having the greatest number of functional leaves (11); the others completed their cycle with fewer than 11 leaves because most were completely infected by the diseases.

At the beginning of the experiment, the highest intensity levels were ob-

---

**Figure 1**: Incidence of climatic conditions on the development of black and yellow Sigatoka (May 1998 - April 1999).
served on the lower leaves of the plants. As time passed, the disease spread to the upper leaves, showing that disease intensity is related directly to the leaf emission.

When the inflorescence appeared some 342 days after planting, the lower leaves, and especially those in positions 11, 12, 13 and 14, displayed higher disease indexes. This is the result of the size of the plants and the larger leaf area, with greater risk of reception of inoculum for future infection. At the end of the study, 50% of the clones had fewer than four functional leaves. At harvesting, individuals 8, 15, 16, 41 and the controls had only one leaf and this was at grade 5 disease intensity (> 50%); this intensity was closely linked to the climatic conditions during the period.

No promising clones were detected in general with regard to resistance to yellow or black Sigatoka. Information concerning the intensity of the diseases for six clonal plants with the lowest indexes for leaves 6, 7, 8 and 9 are shown in Table 1. The final intensity is over 40% for the irradiated clones and there is no significant difference compared to the control. Among these individuals, clone 57 displayed the greatest final disease intensity at 70.48% for the leaf 6. Most of the clones displayed high disease intensity indexes after shooting of the inflorescence. Among them, clones 9 and 57 displayed maximum intensity (100%) on leaf 9 and average intensity increased on the oldest leaves 8 and 9. In agreement with the findings of Belalcázar et al. (1994), analysis of the percentages of maximum disease intensity clearly shows whether the clones are resistant or susceptible, especially by evaluation of leaf 9.

The clones were therefore classified as ‘highly susceptible’ in this work. Both the intensity index and that of the youngest spotted leaf behaved in a very heterogeneous manner during the inflorescence shooting period (342-432 days after planting), when the greatest variation was observed in relation to time. From then onwards, the plants stopped leaf emission and began the process of translocation of nutrients to the inflorescence. As a result, the leaves were weakened and became more susceptible to the diseases. This was augmented by climatic conditions (temperature 21°C, relative humidity 75% and cumulated precipitation 100 mm) encouraging the development of the diseases and allowing them to spread over the entire leaf surface of the plants. All this, together with the fact that the optimum number of leaves needed for a satisfactory bunch (minimum 8 leaves) was not conserved, resulted in bunches with strongly reduced quality and weight (average 12 kg) (Table 2).

The behaviour of the clones most resistant to Sigatoka diseases and its effect on the production parameter can be seen in the same table. Some differences between the epidemiological parameters were observed in these individuals and were to have repercussions on crop yield. As a whole, there were no significant differences between these and the youngest leaf spotted (YLS) variable. Individuals 5, 16, 42, 68, 81 and 107 displayed the highest disease intensity indexes during the study.

**Conclusion**

The results presented above show that mutagenesis caused by irradiation with $^{60}$Co did not give the cultivar ‘Dominico Hartón’ any kind of tolerance to attack by yellow and black Sigatoka. Studies performed by Cervantes (1997) show that irradiation with $^{60}$Co

<table>
<thead>
<tr>
<th>Clone*</th>
<th>Leaf</th>
<th>Final intensity (%)</th>
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<tbody>
<tr>
<td>9</td>
<td>6</td>
<td>44.44</td>
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<tr>
<td></td>
<td>7</td>
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<td>9</td>
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</tr>
<tr>
<td>15</td>
<td>6</td>
<td>52.42</td>
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<tr>
<td></td>
<td>7</td>
<td>48.69</td>
</tr>
<tr>
<td></td>
<td>8</td>
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<tr>
<td></td>
<td>9</td>
<td>63.41</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>7</td>
<td>49.58</td>
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<td>47.66</td>
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<tr>
<td></td>
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<td>44.32</td>
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<td></td>
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<td>40.95</td>
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<td></td>
<td>9</td>
<td>43.33</td>
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<td>Control</td>
<td>6</td>
<td>48.24</td>
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<td></td>
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<td>48.50</td>
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<td></td>
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<td>47.79</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>45.96</td>
</tr>
</tbody>
</table>

* Clones harvested at different dates.

Table 1. Relation between the percentage of final intensity of black or yellow Sigatoka in clones and the lowest average severity taking into account the position of the leaf after inflorescence formation.

<table>
<thead>
<tr>
<th>Clone*</th>
<th>Cycle (days after planting)</th>
<th>YLS</th>
<th>NLE</th>
<th>Bunch weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>528</td>
<td>5</td>
<td>8</td>
<td>8.00</td>
</tr>
<tr>
<td>15</td>
<td>493</td>
<td>5</td>
<td>10</td>
<td>12.50</td>
</tr>
<tr>
<td>39</td>
<td>528</td>
<td>4</td>
<td>10</td>
<td>5.60</td>
</tr>
<tr>
<td>57</td>
<td>528</td>
<td>4</td>
<td>8</td>
<td>8.70</td>
</tr>
<tr>
<td>59</td>
<td>493</td>
<td>5</td>
<td>10</td>
<td>8.00</td>
</tr>
<tr>
<td>82</td>
<td>473</td>
<td>4</td>
<td>10</td>
<td>10.00</td>
</tr>
<tr>
<td>Témoin</td>
<td>486</td>
<td>5</td>
<td>9</td>
<td>10.60</td>
</tr>
</tbody>
</table>

YLS = youngest leaf spotted
NLE = number of leaves at evaluation.

Table 2. Behaviour of six irradiated ‘Dominico Hartón’ clones with regard to the cycle, the youngest leaf spotted, the number of leaves at evaluation and bunch weight (kg).
at different levels or degrees induced mutations in ‘Williams’ banana that had negative effects on the phenotypic qualities of the plant and the fruit, making the latter unfit for sale. This somewhat reduces hopes for genetic improvement using this mutagenic agent.

Acknowledgements
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References


Material and methods
The data were collected in a banana zone (Musa AAA, cv. ‘Valery’) considered to be highly productive. The plantation is 29 years old and located on the Caribbean coast of Costa Rica. It currently has a density of 1750 plants/ha.

Trimming was performed two weeks after the shoots of the inflorescence in all cycles and included the removal of the male flowers and the false hand.

The following treatments were performed on bunches with eight, nine and ten true hands at flowering: 1) removal of one true hand and 2) removal of two true hands.

A hand is considered to be ‘false’ when at least one set of pistillate flowers develops abnormally (with undeveloped ovaries for example) or if staminate flowers are present. A group of pistillate flowers whose gynae西亚 develops normally is considered to be a true hand.

Trimming was performed at random in a 5-ha area, as the different types of bunches appeared. Five trimming operations were performed at two-monthly intervals in April, June, August, October and December. In conformity with the plantation programme, fruits were harvested during each 11th week after trimming in the first three cycles and during weeks 11 and 12 for the last two. It was considered that each bunch was a repetition. A total of 416 bunches were appraised.


The dimensions of the fruits in each bunch were recorded in the second, penultimate and last hands. In the bunches that did not have the same number of true hands (non-equivalent bunches), the treatments were compared in the last remaining hand (LRH) in addition to the second hand. In bunches with the same number of true hands (equivalent bunches), the last comparable hands (LCH) were compared in addition to the second hand.

The LRH is defined as the last distal hand present after one of the two trimming treatments (Figure 1). The LCH is defined as the last distal hand present after the most intense trimming treatment. It is the fifth hand in eight-hand bunches, the sixth hand in nine-hand bunches and the seventh hand in ten-hand bunches.

The following parameters were evaluated:

a) bunch weight
b) grade (1/32") of the central fruit (outer row) in the second hand, in the last remaining hand (LRH) and in the last comparable hand

c) finger length (cm) of the central fruit (outer row) of the second hand, the LRH and the LCH.

The two methodologies were compared by using the same set of data. In the first, non-equivalent bunches and the LRH were used for comparison purposes in addition to the second hand. In the second, groups of equivalent bunches and the LCH were used for comparison, in addition to the second hand. Analysis of variance was performed on the data in both cases to compare the effects of the treatments.

Results

Analysis of all the data in which the number of hands was not taken into account or where the LRH was used in addition to the second hand to compare fruit dimensions (Table 1) reveals significant differences (P < 0.01) between trimming treatments with regard to the grade and length of the central fruit in the LRH. As trimming intensity increased, bunch weight decreased (P < 0.01). The dimensions of the central fruit in the second hand were not affected (P > 0.36) by trimming intensity.

Analysis of all the data in which the number of hands in the bunch was taken into account and where the LCH was used in addition to the second hand to evaluate fruit grade and finger length (Table 2) did not reveal significant differences (P > 0.40) between the treatments, regardless of bunch size. However, analysis allowing for the number of hands in the bunch and using the LRH for comparison (Table 2) reveals significant differences (P < 0.02) between the treatments, regardless of bunch size. Bunch weight decreased with increasing trimming intensity for the bunches with 9 and 10 hands (P < 0.01) but not for those with 8 hands (P > 0.15). The dimensions of the central fruit in the second hand of the bunches with 8, 9 and 10 hands were not differentiated (P > 0.09) by trimming intensities.

Discussion

An experiment can be defined as ‘a research study in which one deliberately manipulates one or more independent variables (supposed causes) in order to analyse the consequences of this manipulation for one or more related variables (supposed effects) in a situation controlled by the experimenter’ (Hernández et al. 1998).

The independent variables (causes) represent the experimental treatments which refer to experimental entities. The experimental entities assigned to the treatments must be equivalent in all respects (homogeneous) or their variability must be duly controlled within the framework of the experimental protocol.

Table 1. Measurements ± standard deviation of bunch weight, grade and length of the central lower finger (Musa AAA, cv. ‘Valery’) of the second and last remaining hand (LRH) according to the trimming intensity (TI). All the bunches with 8, 9 and 10 hands at flowering were taken into account.

<table>
<thead>
<tr>
<th>TI</th>
<th>n</th>
<th>Bunch weight (kg)</th>
<th>Fruit grade</th>
<th>Finger length (cm)</th>
<th>Fruit grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2nd hand</td>
<td>2nd hand</td>
<td>LRH</td>
<td>LRH</td>
</tr>
<tr>
<td>2</td>
<td>191</td>
<td>25.53 ± 0.35</td>
<td>43.26 ± 0.12</td>
<td>25.92 ± 0.11</td>
<td>39.50 ± 0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd hand</td>
<td>2nd hand</td>
<td>LRH</td>
<td>LRH</td>
</tr>
<tr>
<td>3</td>
<td>225</td>
<td>23.84 ± 0.29</td>
<td>43.40 ± 0.12</td>
<td>26.00 ± 0.09</td>
<td>40.48 ± 0.14</td>
</tr>
</tbody>
</table>

1 Corresponding to the number of hands removed.

2 One grade unit is 1/32 of an inch (0.79375 mm).
In general, the effect of trimming banana bunches has been studied without consideration of the number of true hands present at flowering. Under these conditions, it is very likely that non-equivalent groups received different treatments, invalidating the comparison because of the resulting approximation. In this case, the negative consequences for the quality of the experiment are even more marked by the use of the LRH for recording fruit dimensions (grade and finger length). The position of the finger in the bunch depends on the size of the latter and the trimming intensity. We know that finger length in a banana bunch (cv. 'Valery) decreases from the first hand to the last (Jaramillo 1982), with a more marked decrease from the fifth hand onwards. As a result, the LRH cannot achieve the equivalence between hands required for the differences between treatments to be assessed objectively. For this reason, it is inadequate for comparison of different trimming intensities.

The sources of invalidity mentioned above can be eliminated by considering each bunch as an experimental entity, by applying treatments at random in the field, by comparing bunches with the same number of hands at flowering and by comparing hands in identical positions on the bunch (equivalent bunches and hands), as performed by Vargas et al. (1999).

The results do not show that the highest trimming intensity (removal of three true hands) results in an increase in the dimensions of fruits of the cultivar 'Valery' in comparison with the lowest intensity (removal of two true hands). Likewise, in agreement with the previous analysis, it is confirmed that the decrease in bunch weight is the result of trimming.

The different conceptual analysis of the same set of data can explain the difference in the results displayed in the research work based on one or other of the concepts. As a result, the methodology based on the use of non-equivalent bunches and hands and generally used for evaluation and analysis should no longer be applied in research on the trimming of banana bunches. Its use could lead to erroneous results, as is demonstrated in this study. Instead, researchers should use the second method based on the use of equivalent hands and bunches.

References


Table 2. Measurements ± standard deviation of bunch weight, grade and length of the central lower finger (Musa AAA, cv. ‘Valery’) of the second and last comparable hand (LCH) according to the trimming intensity (TI) and the total hands (TH) in the bunch. LRH = 6th and 5th if TH = 8; 7th and 6th if TH = 9; 8th and 7th if TH = 10; LCH = 5th if TH = 8, 6th if TH = 9 and 7th if TH = 10.

<table>
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<tr>
<th>TH</th>
<th>n</th>
<th>TI</th>
<th>Bunch weight</th>
<th>Grade grade (cm)</th>
<th>Finger length</th>
<th>Grade grade (cm)</th>
<th>LRH finger length</th>
<th>Grade grade (cm)</th>
<th>LCH finger length</th>
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<td>8</td>
<td>40</td>
<td>2</td>
<td>20.41 ± 0.47</td>
<td>43.19 ± 0.22</td>
<td>25.71 ± 0.22</td>
<td>39.60 ± 0.26</td>
<td>21.92 ± 1.18</td>
<td>41.01 ± 0.21</td>
<td>23.00 ± 0.17</td>
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<td>3</td>
<td>19.43 ± 0.47</td>
<td>43.47 ± 0.25</td>
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<td>23.21 ± 0.18</td>
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<tr>
<td>9</td>
<td>73</td>
<td>2</td>
<td>24.24 ± 0.39</td>
<td>43.11 ± 0.18</td>
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<td>39.56 ± 0.18</td>
<td>21.68 ± 0.16</td>
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<td>22.55 ± 0.19</td>
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<td>26.02 ± 0.14</td>
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<td>22.44 ± 0.14</td>
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<tr>
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<td>2</td>
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<td>26.29 ± 0.18</td>
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<td>27.49 ± 0.34</td>
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<td>39.99 ± 0.17</td>
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</tr>
</tbody>
</table>

1) One grade unit is 1/32 of an inch.
Consumer acceptability of introduced bananas in Uganda

K. Nowakunda, P.R. Rubaihayo, M.A. Ameny and W. Tushemereirwe

Banana productivity in Uganda has been declining since the 1970’s (Hartmanns 1989), mainly due to low soil fertility, pest and disease build up, low germplasm diversity and a host of socioeconomic constraints (Rubaihayo and Gold 1991). All the AAA-EA cooking bananas are susceptible to black Sigatoka, banana weevils and nematodes (Tushemereirwe 1996).

The use of disease and pest resistant banana cultivars has been suggested as the most feasible solution to these problems (Ortiz and Vuylsteke 1998), and consequently, a number of banana hybrids and landraces resistant or tolerant to mainly black Sigatoka and/or Fusarium wilt have been introduced into Uganda.

The physical, chemical and sensory characteristics of these cultivars were determined to establish their quality profile. The agronomic attributes of importance to banana end-users included maturity period and attainment of acceptable eating quality at an early stage of development.

This paper reports the results of consumer acceptability of 14 introduced banana and plantain cultivars for cooking and juice production.

Materials and methods

The characteristics of the 14 cultivars together with East African Highland banana landraces used in the study are presented in Table 1. The most common landrace cultivars Mbwazirume, Kisansa (AAA-EA) cooking bananas, Ndizi (AB), Musa-Kayinja (ABB) and Entundu (AAA-EA) beer banana were used as controls in a completely randomized block design experiment.

The fruit filling period was recorded as the period from shooting to the day when at least one finger indicated signs of ripening at which stage the bunch was harvested (Palmer 1971). The bunch weight (in kg) was taken at harvest using a weighing scale (BFK-265-0308, 60, Fisher, UK). The finger weight was determined by weighing five individual fingers from the second of the bunch on a Mettler (P1200, Fisher, UK) electronic balance. The same fingers were used for finger length, girth and peel and pulp weights. Peel and pulp weights were determined by separating the peel and pulp by hand peeling with a stainless steel knife and weighing the peel and pulp separately. Green-life was determined by difference in days between harvesting and when the second hand showed first signs of ripening by colour change from deep green to light green (Dadzie and Orchard 1997). The samples for green-life monitoring were harvested one week to the expected physiological maturity as defined by Palmer (1971). Tannin levels were determined using the Vanillin based assay as described by Broadhurst and Jones (1978).

Sensory characteristics and acceptability were determined by boiling peeled bananas in 1L of water. Six grams of table salt were added to the bananas and boiled until they were well cooked. This method of preparation was preferred to the traditional steaming and mashing (muwumbo) to avoid presentation bias.

Fifteen panellists were selected on the basis of functional taste buds using dilute solutions of basic tastes: Sweet (Sucrose at 8 g/l), Salty (Sodium chloride, 1.5 g/l), Sourness (Citric acid, 0.25 g/l), Bitterness (caffeine, 0.05 g/l) (Bainbridge et al. 1996).

The selected panellists were taken through a series of tests involving non-experimental bananas to allow them to learn the various descriptors of banana quality characteristics. Experimental samples were coded with four digits to eliminate name bias and presented to the panellists. The panellists were requested to score the samples using a 6-point hedonic scale with 1 = extreme approval and 6 = extreme disapproval of a given attribute (Larmond 1987, Jellinek 1985) for the following characteristics: taste, texture, colour and acceptability. Juice extraction was done using methods described by Kya-muhangire (1990).

The data were analyzed by the Generalized Linear Model (GLM) and analysis of variance (Mead et al. 1993). The means were separated using the Fisher’s Unprotected LSD test at 0.05 level of significance (Anon. 1994). The correlation matrices were obtained using the Minitab correlation programme.

Results and discussion

Yield characteristics

The results of yield characteristics are presented in Table 2. The FHIA hybrids had similar maturing time as the AAA-East African highland landrace cultivars, which gave FHIA hybrids an ad-

Table 1. Characteristics of cultivars/hybrids used in the study.

<table>
<thead>
<tr>
<th>Name</th>
<th>Genome</th>
<th>Origin</th>
<th>Characteristics</th>
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<td>FHIA</td>
<td>R</td>
</tr>
<tr>
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<td>AAAA</td>
<td>FHIA</td>
<td>R</td>
</tr>
<tr>
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<td>AAAA</td>
<td>FHIA</td>
<td>R</td>
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<td>FH6A-17</td>
<td>AAAA</td>
<td>FHIA</td>
<td>R</td>
</tr>
<tr>
<td>TMPx582/4</td>
<td>AAB</td>
<td>IITA</td>
<td>R</td>
</tr>
<tr>
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<td>ABB</td>
<td>IITA</td>
<td>T</td>
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<td>AAB</td>
<td>IITA</td>
<td>T</td>
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<td>T</td>
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<td>IITA</td>
<td>T</td>
</tr>
<tr>
<td>TMPx7002/1</td>
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<tr>
<td>Pisang Ceylan</td>
<td>AA</td>
<td>IITA</td>
<td>T</td>
</tr>
<tr>
<td>Yangambi km5</td>
<td>AAA</td>
<td>IITA</td>
<td>R</td>
</tr>
<tr>
<td>Saba</td>
<td>ABB</td>
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<td>T</td>
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</tr>
<tr>
<td>Kisansa</td>
<td>AAA</td>
<td>Landrace</td>
<td>R</td>
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<td>Entundu</td>
<td>AAA</td>
<td>Landrace</td>
<td>S</td>
</tr>
<tr>
<td>Kisubi</td>
<td>AB</td>
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<td>S</td>
</tr>
<tr>
<td>Pisang awak</td>
<td>ABB</td>
<td>Landrace</td>
<td>S</td>
</tr>
</tbody>
</table>

5 = Susceptible, T = Tolerant, R = Resistant.

* Cultivars used as control for cooking tests.
+ Cultivars used as control for juice yield.
vantage over the IITA hybrids. However, both the FHIA and IITA hybrids produced significantly (P < 0.05) heavier bunches than the East African highland cooking bananas suggesting a clear advantage over the East African highland banana cultivars in the study with respect to bunch sizes. Banana producers and consumers prefer cultivars with big bunches (Ssemwanga and Thompson 1994, Dadzie and Orchard 1997).

Fruit characteristics

The results of peel weights indicated that FHIA-01, FHIA-03, FHIA-23 and the IITA hybrids were not significantly (P < 0.05) different from Mbwazirume, a local AAA-EA cooking banana landrace. Saba, Yangambi km5 and Kisansa respectively had the lowest percentage of peels indicating more pulp which is a clear advantage for cooking, juice, dessert and roasting bananas. All the IITA hybrids had longer fingers and lower peel percentages compared to the rest of the bananas.

Data from fruit girth measurements showed that the fruit circumference of Saba and TMPx5511-2 was significantly (P < 0.05) different from Mbwazirume, Yangambi km5, Pisang Ceylan, TMPx548-4 and FHIA-23 had the smallest circumference. Large fingers are a preferred banana characteristic (Dadzie and Orchard 1997) and therefore an advantage.

Shelf life

The results of shelf life study for the banana cultivars harvested at one week before their expected physiological maturity as defined by Palmer (1971) indicated that Kisansa had significantly (P < 0.05) longer shelf life than the other cultivars studied. Bananas are usually harvested when they are a mature green for ease of transportation to the markets. The consumers also use the bananas piecemeal over time ensuring a clear advantage for banana cultivars with a long shelf life.

The EA-AAA cooking banana landraces had significantly (P < 0.05) lower dry matter than the other cultivars studied suggesting considerable disadvantage in terms of yield improvement during breeding (Anon. 1993). The results of tannin (polyphenols) and sensory analyses of the cultivars indicated that the EA-AAAA cooking banana landraces had significantly (P < 0.05) lower than the traditional bunch cultivars which had an unacceptable astringent taste (Table 3).

Sensory analysis

The results of the sensory analysis for taste, texture, colour, flavour and acceptability of the cooked bananas indicated that the introduced bananas and plantains had significantly (P < 0.05) poorer scores than the East African highland bananas (Table 3). The tex-
tural attribute in bananas has been classified in sensory terms as 'hard', 'medium' or 'soft' (Ssemwanga et al. 1996). The panelists rejected the tactual attributes of the hybrids describing it as 'hard' and therefore 'unacceptable'. Ugandan consumers dislike cooked bananas, which lack a 'soft' texture (Ssemwanga and Thompson 1994). Results also indicated that colour and taste attributes in the introduced bananas were significantly (P < 0.05) poorer than the AAA-EA cooking bananas. The panelists complained of a puckering sensation in the mouth caused by the introduced cultivars and poor flavour implying that they are inferior as cooking bananas.

General acceptability
General acceptability, the final judgement of the panelists for the cultivars, summing up all the perceptions indicated that all the introduced banana cultivars were significantly (P < 0.05) inferior to the AAA-EA cooking bananas. All the IITA hybrids and FHIA-03 scored 5 and above indicating total rejection. FHIA-01 had an acceptability score of 3.0 which was the closest to the report that the hybrid bananas. All the IITA hybrids and FHIA-03 scored 5 and above indicating total rejection. FHIA-01 had an acceptability score of 3.0 which was the closest to the

<table>
<thead>
<tr>
<th>MD</th>
<th>BW</th>
<th>FW</th>
<th>FL</th>
<th>FC</th>
<th>PP %</th>
<th>DM %</th>
<th>TSS %</th>
<th>TNN</th>
<th>PR</th>
<th>AS</th>
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<th>TT</th>
<th>FV</th>
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<tr>
<td>TSS %</td>
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<td>0.793*</td>
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<td>0.901*</td>
<td>0.818*</td>
<td>0.766*</td>
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</tbody>
</table>

MD = Maturity date (fruit filling period); BW = Bunch weight; FW = Fruit weight; FL = Fruit length; FC = Fruit circumference; PP % = Percentage peels; DM % = Percentage dry matter; TSS % = Percentage total soluble solids; TNN = Tannin (abundance values); PR = Protein; AS = Total Ash; FB = Crude fibre; TT = Taste; FV = Flavour; TX = Texture; CL = Colour; AC = Acceptability.

* Significant coefficients.

The results of correlation matrix and ANOVA analysis indicated that the relationship between tannin and colour was significant (P < 0.05) (r = 0.77) suggesting that the cultivars with high tannin negatively affects the appearance of the cooked bananas. The correlation coefficient between texture and acceptability as observed by Ssemwanga and Thompson (1994) and Sebasigari (1996).

The correlation between fibre and acceptability (r = 0.59) was significant (P < 0.05) suggesting that the amount of crude fibre was important for acceptability. The correlation between dry matter and texture was significant (P < 0.05) (r = 0.61) suggesting that cultivars with high dry matter would have a hard texture and hence become unacceptable. This may account for the low acceptability and hard texture of the IITA hybrids since they were found to have high dry matter. The relationship between tannin and texture suggested that cultivars with high tannin had unacceptable texture. The relationship between maturity date and acceptability was also significant (P < 0.05) (r = 0.68) suggesting that the cultivars that take longer to mature were less acceptable.

The results of juice yield indicated that only FHIA-03, FHIA-01, Yangambi km5 and Saba yielded juice (Table 5). FHIA-03 yielded a significantly (P < 0.05) higher percentage of juice than the landrace Entundu and the locally adapted Musa-Kayinja and Kisubi. Yangambi km5, FHIA-01, and Saba had similar juice yields as Entundu, a traditional AAA-EA juice banana. The low juice yielders produced juice of significantly (P < 0.05) higher brix than the high juice yielders. Normally, juice is consumed or processed further after dilution to acceptable sweetness. Acceptable sweetness has been established to coincide with a brix of between 12%-14% (Pekke, personal communication) which explains why banana juice is normally diluted before drinking. What appears to be a disadvantage of having lower brix is compensated for by higher juice yields. The pH of the juices from FHIA-01 and Entundu was similar and significantly (P < 0.05) higher than that of other cultivars that could produce juice. The pH is an important attribute of juices because it influences the levels and type of contamination and therefore the kind of preservation necessary (Jay 1987). Low pH has lower levels of microbial contamination and, therefore, less need of stringent preservation methods (Jay 1987).

The taste of Kisubi juice was scored as significantly (P < 0.05) better than the juices from most of the other cultivars studied. This cultivar also had the lowest pH (4.5). Saba and FHIA-01 produced juice with significantly (P < 0.05) better mouthfeel than local beer banana cultivars. Mouthfeel is a measure of smoothness of the juice hence an important quality characteristic (Koffi et al. 1991).

The good yield and characteristics of the juice combined with big bunches, black Sigatoka and Fusarium wilt resistance make FHIA-01, FHIA-03, Yangambi km5 and Saba good candidates for juice/beer production in places of the country where brewing is an important
economic activity and the traditional cultivars are being wiped out by pests and diseases.

Conclusions
Results of the study indicated that while the introduced cultivars had big bunches and fruits, their cooking qualities were unacceptable to consumers due to high tannin, hard texture and poor taste compared to AAA-EA cooking bananas.

Cultivars FHIA-01, FHIA-17 and FHIA-23, however, had ratings that could make them acceptable for cooking in parts of the country where the cooking banana landraces are disappearing. Cultivars FHIA-01, FHIA-03, Yangambi km5 and Saba with good quality juice can replace the traditional local juice producing cultivars where these are disappearing.

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Tushemereirwe W. K. 1996. Factors influencing the expression of leafspot diseases of highland bananas in Uganda. A Ph.D thesis submitted to the University of Reading, Department of Agriculture, UK.

Table 5. Juice Yield and juice characteristics of the recently introduced banana cultivars.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Genotype</th>
<th>Pulp weight (kg)</th>
<th>Juice yields (%)</th>
<th>Brix (%)</th>
<th>pH</th>
<th>Taste</th>
<th>Colour</th>
<th>Mouthfeel</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-01</td>
<td>AAAA</td>
<td>2.0</td>
<td>63.4bc</td>
<td>20.0bc</td>
<td>5.1a</td>
<td>2.5a</td>
<td>2.0</td>
<td>1.8cd</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>AAAA</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>AAAA</td>
<td>2.0</td>
<td>76.5a</td>
<td>21.70bc</td>
<td>4.7bc</td>
<td>2.8a</td>
<td>2.3</td>
<td>2.8ab</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>AAAA</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>AAAA</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tmpx582-2</td>
<td>AAAB</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tmpx5511-2</td>
<td>ABB</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tmpx548-9</td>
<td>AAAB</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tmpx548-4</td>
<td>AAAB</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tmpx7002-1</td>
<td>AAAB</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pisang Ceylan</td>
<td>AA</td>
<td>2.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yangambikm5</td>
<td>AAA</td>
<td>2.0</td>
<td>67.1b</td>
<td>20.92c</td>
<td>4.8b</td>
<td>2.3ab</td>
<td>2.3</td>
<td>2.0c</td>
</tr>
<tr>
<td>Saba</td>
<td>ABB</td>
<td>2.0</td>
<td>65.3bc</td>
<td>22.00bc</td>
<td>4.6cd</td>
<td>2.5a</td>
<td>2.3</td>
<td>1.5d</td>
</tr>
<tr>
<td>Kisubi</td>
<td>AB</td>
<td>2.0</td>
<td>52.7d</td>
<td>25.58a</td>
<td>4.5d</td>
<td>1.5b</td>
<td>2.3</td>
<td>2.8ab</td>
</tr>
<tr>
<td>Entundu</td>
<td>AAA-EA</td>
<td>2.0</td>
<td>68.5b</td>
<td>19.83c</td>
<td>5.1a</td>
<td>2.8a</td>
<td>2.8</td>
<td>3.0b</td>
</tr>
<tr>
<td>Musa-Kayinja</td>
<td>ABB</td>
<td>2.0</td>
<td>60.5c</td>
<td>24.00ab</td>
<td>4.8b</td>
<td>2.3ab</td>
<td>2.3</td>
<td>2.5b</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td></td>
<td>3.7</td>
<td>0.76</td>
<td>2.86</td>
<td>24.78</td>
<td>21.17</td>
<td>44.59</td>
</tr>
</tbody>
</table>

* Data analysed was that from the seven cultivars which produced juice.

K. Nowakunda and W. Tushemereirwe work at Kawanda Agricultural Research Institute, Banana Programme, PO Box 7065, Kampala, P.R. Rubaihayo and M.A. Ameny at Makerere University, Faculty of Agriculture, PO Box 7062, Kampala, Uganda.
Corm decortication method for the multiplication of banana

Bakelana-ba-Kufimfutu and Mpanda

Banana is an important crop in the Democratic Republic of the Congo, lying in second position after cassava, and the fruits are a very important part of the diet of the population. Dessert bananas are eaten as soon as they are ripe, and plantain is processed to form a paste called ‘Lituma’ or boiled and mixed with other foods. The development of banana cultivation requires the improvement of cultural practices and planting material (suckers). Farmers find it very difficult to obtain sufficient quantities of planting material to increase the size of area under cultivation.

There are several sucker multiplication techniques. It is difficult to obtain suckers in sufficient quantities when they are needed through the natural multiplication method used by most farmers. The false decapitation method found to give good results in experimental trials does not satisfy the requirements of farmers who do not wish to delay their harvests.

Bananas multiplied naturally from suckers have low bunch yields in comparison with tissue culture plants (Adesunkers have low bunch yields in comparison with tissue culture plants (Ade-"

Influence of corm age and the number of cuts on the start of growth of lateral buds, the number of suckers produced and sucker height.

<table>
<thead>
<tr>
<th>Corn age</th>
<th>Number of cuts</th>
<th>Number of days to the start of bud growth</th>
<th>Number of suckers</th>
<th>Sucker height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-flowered</td>
<td>0 cut</td>
<td>47</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>2 cuts</td>
<td>39</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4 cuts</td>
<td>33</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Flowered</td>
<td>0 cut</td>
<td>31</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>2 cuts</td>
<td>27</td>
<td>8</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>4 cuts</td>
<td>18</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>LSD (0.5)</td>
<td></td>
<td>4.50</td>
<td>NS</td>
<td>3.4</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>9.36</td>
<td>52.7</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Two superimposed sheaths determine a lateral bud at the low point or ‘V’ where they meet. The number of buds is therefore the same as the number of leaves possessed by the plant. The buds of old leaves are more visible than those of very young ones. Precautions were taken not to damage the visible buds that had greater potential for development under favourable conditions. After decortication, the apical meristem of the non-flowered corms was damaged to activate the growth of the lateral buds. Regular watering was performed throughout the duration of evaluation. The following parameters were observed:

1) Number of days to the start of bud growth
2) Number of daughter suckers produced by each corm
3) Sucker height at separation from the corm

Each shoot was weaned from the mother corm at the 3-leaf stage. After decortica-
tion, all the corms were planted in a clay substrate.

Results and discussion

The results are shown in Table 1. Statistical analysis of the data reveals significant differences in the number of days to the start of growth of lateral buds and in sucker height.

• Influence of age: the lateral buds develop more rapidly on the flowered plants. This can be explained by the
Improvement | New evaluation in India

Preliminary evaluation of some banana introductions in Kerala (India)

Rema Menon

Banana is the most important tropical fruit crop of Kerala state, which occupies the southwestern portion of the Indian peninsula. Being located within the centre of diversity of cultivated banana, Kerala along with two other south Indian states - Tamil Nadu and Karnataka - are known for the varied genetic resources, especially the AAB, AB and ABB genomic groups under the Eumusa series of edible banana (Stover and Simmonds 1987). Although an array of varieties is grown in Kerala, the French plantain cultivar Nendran (AAB) is the most widespread and highly valued as a dessert and cooking banana. Nearly 50% of the banana production within the state is derived from the commercial cultivation of this variety. Other prominent cultivars include Poovan (AAB), Rachali (AAB), Red Banana (AAA), Dwarf Cavendish (AAA), Robusta (AAA), Kunan (AB) and Monthan (ABB), the cultivation of which is restricted to the home gardens and provides an important source of rural income.

The Banana Research Station (BRS), Kannara, functioning under the Kerala Agricultural University (KAU), has among its major objectives the collection, conservation and evaluation of banana germplasm. The station holds a collection of 225 accessions conserved in field genebank and comprises indigenous and exotic material. The accessions have been characterized and evaluated using the INIBAP/IPGRI Musa descriptors. The present paper outlines the work carried out during 1994-1997 relating to the preliminary evaluation of some banana introductions.

Materials and methods
Twenty-two accessions from INIBAP’s Musa collection (ITC series) received in 1994 through the National Bureau of Plant Genetic Resources (NBPRGR), New Delhi, formed the experimental material. The accessions were received as small suckers of sample size one to two, derived from tissue-cultured plants. The suckers were first established in pots and subsequently transferred to experimental field at BRS. The site is located at an elevation of 58 masl. The average temperature of the region is 28°C and the annual rainfall ranges between 2700 and 3000 mm, distributed between two rainy seasons. Relative humidity varies between 77 and 94%. Observations recorded on the first crop showed that 14 out of the 22 accessions were represented in the station’s banana germplasm. Of the remaining eight, three accessions viz. Three Hands Planty (ITC1132), Three Vert (ITC1127) and Fconah (ITC649) could not be established. Finally the following five exotic accessions were selected for further evaluation (Table 1).

Five suckers of each cultivar were planted in single rows in a compact plot adopting a distance of 2.5 m between rows and 2 m within row. Since three of the test cultivars turned out to plantain types, two indigenous plantain cultivars, Nendran and Myndoli were planted along for comparison. Observations on growth in terms of plant height, pseudostem girth, number of functional leaves at shooting and plant crop cycle were recorded. Other variables observed include bunch weight, number of hands and number of fruits. Pulp/peel ratio and the recovery of chips in the plantain cultivars were also assessed.

Tableau 1. Accessions selected for further evaluation.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cultivar name</th>
<th>Genome</th>
<th>ITC code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Big Ebanga</td>
<td>AAB</td>
<td>1129</td>
</tr>
<tr>
<td>2</td>
<td>Njock kon</td>
<td>AAB</td>
<td>1133</td>
</tr>
<tr>
<td>3</td>
<td>Nyombe</td>
<td>ABB</td>
<td>1124</td>
</tr>
<tr>
<td>4</td>
<td>Yangambi kmS</td>
<td>AAA</td>
<td>1123</td>
</tr>
<tr>
<td>5</td>
<td>Popoulu</td>
<td>ABB</td>
<td>1135</td>
</tr>
<tr>
<td>6</td>
<td>Nendran*</td>
<td>ABB</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Myndoli*</td>
<td>ABB</td>
<td></td>
</tr>
</tbody>
</table>

* Indigenous French Plantain cultivars.

References

Bakelana-ba-Kulimfutu works at the Institut National pour l’Étude et la Recherche Agronomique, BP 2007, Kinshasa I, Democratic Republic of Congo, and Mpanda at the Université Protestante de Kinshasa, Bas-Congo, Democratic Republic of Congo.
Characterization

The cultivated and edible bananas and plantains of the world are closely related to and have, in fact, originated from two wild species, one of which is Musa balbisiana Colla. M. balbisiana is a distinct species in the genus Musa and is reported to be native to the Philippines where it is of widespread occurrence. Its wide range of distribution may be attributed to its high vigour and apparently very high resistance to pests and diseases. However, due to lack of interest or lack of resources, the genetic diversity of M. balbisiana has not yet been studied intensively and no subspecies have yet been described (Shepherd 1988). In the face of rapid biodiversity loss of native plant species in the Philippines, there is an urgent need to estimate the genetic variation and conserve the diversity of plantain find extensive use in the preparation of banana chips, the suitability of the exotic plantain cultivars in comparison to local cultivars for this purpose was assessed. Big Ebanga registered a chips recovery of 34.7% which was higher than that in Nendran and the other plantain cultivars, which was in the range of 29 to 30%.

References


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M. balbisiana germplasm in the country. With these objectives in mind, this research work was undertaken.

A two-year research project entitled, “Genetic Diversity and Morphotaxonomic Variation of Musa balbisiana Colla in the Philippines”, and funded by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) was then started on July 15, 1998. So far, 105 accessions from 24 provinces comprising 10 geo-political regions of the country have been collected and are being maintained at the Institute of Plant Breeding’s (IPB) fruit genebank. Three hills were maintained per accession totalling 306 hills. A duplicate collection is being established at the Bureau of Plant Industry – Davao National Crop Research and Development Center (BPI-DNCRDC), which also maintains the Southeast Asian Banana and Plantain Germplasm Resource Center. Of the 105 accessions, 76 have been characterized for the whole plant, pseudostem, leaf, inflorescence, bract, male flower and fruit characters using the IPGRI Descriptors for Banana (Musa spp.) (IPGRI-INIBAP/CIRAD 1996). Initial observations showed a wide diversity of M. balbisiana in terms of morphological characters. Bunch appearance ranged from lax to very compact. Colour of mature green fruits ranged from green to light green. Of interest was a silvery (waxy) form of M. balbisiana which was noted. In terms of fruit shape, a wide variation was observed ranging from ellipsoid (Figure 1a) to roundish (Figure 1b) with the fruit apex, acute to prominently bottle-necked (Figure 1c). Male
M. balbisiana

the variation observed in the Philippine complement and further characterize peats (SSRs) need to be carried out to caracterization using locus-specific mi-
isozymes are on-going. Molecular char-
acterization using biochemical characterization using

30 INFO

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MusaNews

Asia and the Pacific
A new approach to triploid breeding in banana in Taiwan

Most of the banana cultivars are triploid. They are usually vigorous and completely sterile under natural condi-

tion. Traditionally, there are two ap-

proaches for triploid breeding in ba-
nanas. One of them is to cross triploid plants with pollens from a diploid to produce a tetraploid (3x X 2x ➔ 4x) and then backcross to the diploid parent to produce a secondary triploid (4x X 2x ➔ 3x) (Rowe and Richardson 1975). Another approach is to generate an autotetraploid from a diploid plant using colchicine treatment (2x ➔ 4x) and then cross to a diploid to produce a triploid (4x X 2x ➔ 3x) (Bakry and Horry, 1994). Last year, the researchers of the National Taiwan University, Dr C.T. Shii and Miss C.F. Liu used tissue culture technique and succeeded in producing triploid plants from the endosperm of the developing seeds resulted from fertilization of diploids (Liu 1999, Liu and Shii 1999). This new technique opens the door of a simple and rapid procedure to produce triploids in banana, i.e. 2x X 2x ➔ endosperm culture ➔ 3x.

Another advantage of this approach is that any diploid combination can be formed as long as the endosperm can be obtained after pollination. Further investigation on the practical application of this method in banana breeding is being conducted.

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sis from the endosperm culture of diploid bana-
Rowe P.R. & D.L. Richardson. 1975. Breeding ba-
More information is available from C.Y. Tang,
TBRI, PO Box 18, Chiuju, Pingtung 90403,
Taiwan.

Banana plantation census in Australia
The results of a banana plantation cen-
sus for the period to 30 June 2000 have recently been published by Queens-
land’s Banana Industry Protection Board. There are 1013 properties listed in the census, representing 10,501 hectares of plantations. Cavendish varieties occupy 9,680 hectares (92%) of this area. The most common diseases recorded were yellow Sigatoka (1013 properties), leaf speckle (1013 properties), Panama disease (162 properties) and bunchy top disease (89 properties). Black Sigatoka, bacterial wilt and bact mosaic diseases were not found.
Further information is available from
Mr N. Janetzki, Secretary, Banana Industry Protection Board, c/o Department of Primary Industry, GPO Box 46, Brisbane Q 4001, Australia.

The effects of airborne fluoride pollution on bananas in China
A study was carried out on the causes of banana leaf marginal scorch on ba-
nanas in Dongguan county in China. Leaf scorching has been recognised as
a major constraint to production in this area since 1987 and is thought to be responsible for yield losses of around 20%. The study revealed that the cause of the leaf scorching was airborne fluoride pollution, with the main source of the pollution being brickfields and cement factories. It was noted that dwarf Cavendish was more sensitive to the pollution than plantains and other Cavendish varieties. More information is available from Zhang Hallan and Wu Dinyao, Tropical and Subtropical Fruit Research Lab, South China Agricultural University, Guangzhou 510642, China.

Studies on seeded bananas in Assam, India
In the Northeast regions of India, two types of seeded bananas are commonly used as baby foods. These bananas, known locally as 'Bhikmal' and 'Athiakal', are very hardy, resistant to pests, diseases and drought and are high yielding. Bhikmal in particular is a rich source of energy (114.4 kcal/100g).

High incidence of BBTD is resulting in severe economic losses over a large part of the area where hill bananas are cultivated. It is essential that indexing of suckers (using either ELISA or PCR techniques) is carried out to detect the presence of BBTD at an early stage and disease-free suckers are supplied in order to lessen the impact of the disease and revive hill banana cultivation and the farming economy.

Further information is available from K. Manickam, T. Ganapathy and S. Doraismavy, Department of Plant Pathology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore 641 003, India.

West Africa
A new appropriate technology for rapid multiplication of plantain suckers in Ghana
Plantains and bananas are major starchy staples for Ghanaians. They are of great socioeconomic and nutritional importance and also generate considerable rural income and employment.

The major production constraints include pests (weevils and nematodes) and diseases, especially black Sigatoka, lack of planting materials and declining soil fertility.

To address the disease problems, new resistant/tolerant tetraploid hybrids of banana and plantain were introduced. To improve the planting material situation, a rapid multiplication technique called the split-corm technique was developed. This technique could produce about 8-10 sets from a medium-size corm and would be ready for transplanting after about 8-12 weeks.

A new technique, which can generate more suckers within a shorter period, has been developed. The procedure includes:
1. Create a wooden column about 1.2 m by any convenient length, 30 cm tall and fill with sawdust (the column could be created as a trench and filled with sawdust).
2. Uproot the corm to be used and trim off roots and peel to remove nematodes and weevils.
3. Split corm into two or four parts depending on the size of the corm.
4. Treat the corm pieces with a solution of fungicide e.g. 1% Benlate.
5. Air-dry the treated corms for 24 hours under shade.
6. Plant the corm pieces 15 cm deep into the sawdust with the cut surface downward (preferably near a water source to facilitate irrigation).
7. Build a shed over the column with palm frond or a polyethylene sheet to maintain a humid condition.
8. Irrigate daily.
9. Sprouting starts after 8 days.
10. Excise the new shoots from the mother corm when two green leaves appear and plant in a 7 x 9 cm black polybag filled with 7 parts loamy soil, 2 parts river sand and 1 part well-decomposed poultry manure. Hardening takes one month, after which the plants can be planted in the field.
11. Continue to irrigate the column and remove shoots as they appear.
12. The mother corm will continue to produce healthy shoots for about 5 weeks.

Advantages:
1. Suckers are produced close to the farm which reduces the cost of transport.
2. Disease and pest-free planting materials are produced.
3. Several planting materials are produced within a very short time.
4. All the available buds on the corm are able to express themselves (some of the buds may have been lost by the split corm technique).
5. True-to-type materials are produced.

Further information is available from B.M. Dzomeku, B. Barful, D.K. Yeboah and S.K. Darkney, Crops Research Institute, PO Box 3785, Kumasi, Ghana.

Latin America and the Caribbean
Breeding for the resistance to Panama disease in banana clones 'Manzano' (AAB) and 'Gros Michel' (AAA) through tissue culture and in vitro mutagenesis
During the past years, in vitro culture combined with induction and induced somatic mutation breeding became more effective due to the development accomplished in genetic breeding via biotechnological techniques. This project began with the aim to breed, on a laboratory level and then in the field, resistant or tolerant to Panama disease (Fusarium oxysporum var. cubense), races 1 and 2, and somaclones from the susceptible clones 'Manzano' (AAB) and 'Gros Michel' (AAA). Vitroplants of both clones first were initiated from the buds and induced to form multiple
buds, then, they were treated with physical mutagenic agents (Gamma rays), Co60 source. The inoculations were carried out with different fungus isolates from the INIFAT - 1 strain during four in vitro development cycles with a 3 x 105 spores/ml solution during 30 minutes, which resulted to be more pathogenic in previous studies. Once the process concluded, the vitroplants were planted in beds containing organic soil contaminated with the remains of the plants infected with Fusarium oxysporum. After 60 days, the vitroplants that has not presented leaf yellowing symptoms, were reinoculated with a spore solution from the same strain puncturing the base of the pseudostem. After 6 months, symptomless vitroplants were transplanted in the field infected with pathogen in order to evaluate the disease incidence. 42 somaclones were selected which were again multiplied in vitro until 100 individuals were obtained from each one (clonal line), evaluating once more their behavior to the disease both in beds and in the field. Finally, there were selected nine somaclones of the clone ‘Gros Michel’, which presented infection signs in the field lower than 30%. In the derived material of the ‘Manzano’ clone, all the selections were classified susceptible after the first cycle in the clonal study. The resistant somaclones with favorable agronomic characters were in vitro micropropagated and their yields are under study at this time.

Information provided by I. Bermúdez, P. Orellana, N. Veitía, C. Romero, J. Clavelo, L. García and M. Acosta, Instituto de Biotecnología de las Plantas, Universidad Central de las Villas, Carretera a Camajuaní Km 5 1/2, Universidad Central “Martha Abreu” de las Villas, Santa Clara, Villa Clara, Cuba (e-mail: porellana@uclv.etc.csa.cu; Tel.: 81360 – 81693) y L. Herrera I., Facultad de Ciencias Agropecuarias, UCLV, Santa Clara, Villa Clara, Cuba.

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**Thesis**

**Postharvest physiology, ripening and quality evaluation in banana (Musa spp.) fruits**

PhD Thesis submitted in August 2000 at the Faculty of Agricultural and Applied Biological Sciences, Katholieke Universiteit Leuven (KUL), Belgium.

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_Satisfactory objective methods to evaluate banana fruit (Musa spp.) quality from harvesting, ripening to retailing are still lacking. An objective method for banana quality evaluation is crucial to the success of the market industry and consumer health.

The feasibility of using electrical impedance spectroscopy to evaluate postharvest banana quality and ripening is presented in this dissertation. Low frequency resistance and “Py” increased with ripeness and “low” values (depending on peel colour) mostly correlated with abnormal pulp condition. Electrical impedance technique has the potential of relating internal quality and peel colour during banana ripening.

Banana quality at any given time is defined by interrelated basic parameters. Combinations of internal and external quality parameters confer an expected degree of excellence. However, it is difficult to define the exact characteristics to make the distinction.

The application of appropriate postharvest techniques extended ‘green-life’, ripening-shelflife periods and maintained quality but did not improve after-harvest quality. Harvest maturity is therefore essential for desired banana quality. Banana handling, storage conditions and operational practices influence changes in the pulp, peel and shelflife. However, changes were completely dependent on fruit’s physiology and biochemistry.

Physiochemical changes in bananas subjected to various handling practices and environmental conditions were monitored. Ethylene production, respiration rate, peel colour, soluble solids content, pulp firmness and electrical impedance were potential indicators (initiator in the case of ethylene) for ripening, influence changes and storage life.

Examined changes in bananas induced with ethylene indicate the significant effect of temperature on ripening. However, significant transient delay in pulp softening and peel discoloration occurred in ‘natural’ ripened fruits. Parameters such as 1-aminocyclopropane-1-carboxylic acid (ACC), chlorophyll content and pulp firmness jointly lends credibility to observed changes. Temperature along with ethylene induction sometimes led to uncontrolled ripening. Exogenous ethylene induced autocatalytic ethylene production. Within an acceptable temperature range (14-18°C) and relative humidity (85-95%) bananas ripened in 4-8 days.

Cold damage symptoms occurred in bananas stored below 12°C. The degree of damage at a certain temperature depends on the exposure time. Symptoms became visible upon transfer to favourable temperatures or during subsequent ripening. The registration of only the pulp temperature was not enough to explain the observed final fruit quality.

Controlled hot air treatment of green bananas induced changes associated with banana ripening. The information generated will no doubt help in extending the use of hot air treatment as an alternative to ethylene induction for banana ripening.

The use of peel colour as a single indicator of ripening is erroneous due to differences dependent on the time and place and the evaluator. The peel colour attribute can better be measured objectively as a forward step in quality evaluation.
Early screening of *Eumusa* and *Australimusa* bananas against root-lesion and root-knot nematodes

PhD Thesis submitted in March 2000 at the Faculty of Agricultural and Applied Biological Sciences, Katholieke Universiteit Leuven (KUL), Belgium.

Ruth Stoffelen

Screening of bananas (Musa spp.) for resistance to root-lesion and root-knot nematode species was under study. The work was conducted in three steps: (i) standardization of the screening procedure, (ii) screening of 68 Musa varieties for resistance to banana nematodes during the early vegetative growth stage and (iii) evaluation of three important aspects related to screening experiments: variability in reproductive fitness of nematode populations, variability in root architecture of banana varieties and the interaction between nematode reproduction and root development.

In a first step, a screening procedure for evaluation of resistance of bananas to root-lesion and root-knot nematode species during the early vegetative growth stage was developed. In addition, the screening procedure was adapted for screening under in vitro conditions. During the second step, 68 *Eumusa* and *Australimusa* bananas were evaluated for resistance to *Radopholus similis*, *Pratylenchus coffeae* and *Meloidogyne* spp. in an early vegetative growth stage. Two new sources of resistance to *R. similis* were found in the *Australimusa* section (*Fei* bananas). No sources of resistance to *P. coffeae* and *Meloidogyne* spp. were identified.

In the third step, nematode reproduction, banana root development and their interaction was studied. Variability in reproductive fitness on carrot discs was observed for four *R. similis* populations, but not for three *P. coffeae* populations. Diversity in root architecture (lengths of all root types) was observed for 11 banana varieties grown in hydroponics. Finally, the interaction between banana root growth and nematode reproduction was studied during 4 months. Root growth was a dynamic process consisting of a lag phase, followed by three flushes of root emergence. Nematodes reproduced in all root types and reproduction depended on the presence of fresh roots. Evaluation of banana root growth and nematode reproduction during a 1-year study revealed that environmental effects influenced both parameters.

The screening procedure can be optimized by (i) using the same nematode population to avoid the influence of variability in reproductive fitness, (ii) including a susceptible reference banana cultivar so that environmental effects can be detected and (iii) adapting the inoculation and analysis to the banana root growth.

**Announcements**

15th Nematological congress on Integrated nematode control in the new millennium

Skukuza, South Africa, 20-24 May 2001

The Nematological Society of Southern Africa (NSSA) is presenting the 15th Nematological Congress at Skukuza, Kruger National Park, South Africa from 20 to 24 May 2001. The congress will include papers and poster sessions. Workshops on new or interesting topics can be organized. A visit to the banana growing areas and a PROMUSA meeting from 24 to 26 May 2001 will follow the congress. The meeting will be held at Cybele Guest House, Kiepersol, Mpumalanga, South Africa.

The organizing committee invites you to present one or more papers or posters on any aspect of the science of nematology at the symposium. Contributions should preferably be in English.

Posters (110 cm x 90 cm) will be on continuous display for the duration of the symposium. A 5-minute presentation will be allowed per poster to discuss the contents, with 5 more minutes for discussion. Abstracts should be in English and not exceed 250 words. They will be published in African Plant Protection. Abstracts should preferably be sent by e-mail to mieke@itsc.agric.za as an attached file in the latest possible versions of Microsoft Word or Word Perfect.

Alternatively, hard copies should be sent to M. Danee, ARC-Institute for Tropical and Subtropical Crops, Private Bag X11208, NELSPRUIT 1200, South Africa.

**Important dates**

Abstract submitted: 15 January 2001

Last date for registration: 15 January 2001

Acknowledgement of receipt of abstract: 28 February 2001

Congress Address

Nelspruit 1200

Telephone: (27) 13 752 2071

Fax: (27) 13 752 3854

E-mail: mieke@itsc.agric.za

More details and registration form are available from: http://www.inibap.org/actualites/nssa_eng.htm

**IVth International scientific seminar of plant health**

(2nd announcement)

Varadero, Cuba, 11–15 June 2001

The Centro Nacional de Sanidad Agropecuaria (CENSA) and the Instituto de Investigaciones de Sanidad Vegetal (INISAV) announce the IVth International scientific seminar of plant health and several other scientific meetings that will take place in Varadero, Cuba, from 11 to 15 June 2001 at the International Conventions Center “Plaza América”.

In this forum will be discussed the problems and more recent results, as well as the tendencies of the plant health and plant protection for the new millennium.

Eight scientific meetings will take place during the event and among them, the International workshop on pests and diseases in banana: current situation and challenges for the new century.

Scientists, specialists and students linked to the plant health and plant protection are invited to submit the summaries of the papers to be presented as posters or oral presentations. A copy of the summaries should be sent before March 30, 2001 by e-mail at: varadero@hotmail.com with copy to the President of local organizing committee of the specific meeting that you want to participate. Regarding the workshop on pests and diseases in banana, please contact the coordinator, Dr Luis Pérez Vicente at one of the following e-mail

**INFO MUSA — Vol 9, N° 2**
INIBAP News

Events in Thailand

Between 4th and 12th November, a series of meetings and exhibitions took place in Bangkok, Thailand, as part of a unique International Banana Symposium coorganized by INIBAP, the Department of Agricultural Extension and Naresuan University. Her Royal Highness Maha Chakri Sirindhorn, Princess of Thailand, opened the technical sessions on 6th November after a weekend of displays and competitions to identify the best dessert banana, best cooking banana and best banana products. Amongst those exhibiting their work and products in Queen Sirikit’s National Convention Center were Thailand’s top agricultural institutes and industrial companies, as well as organizations from elsewhere in the world. INIBAP participated in the exhibition, using display boards specially made for the occasion. An opportunity was also provided to show the multimedia CD-ROM adapted from the Banana Brochure and newly translated into English. The INIBAP Transit Centre and ASPNET also had popular displays, and each member of ASPNET brought individual posters representing the research and development occurring in their country.

Three days of meetings followed, with sessions running concurrently. A Technology Transfer Session took place for the benefit of over 300 scientists and technicians from the region. Presentations were given on the advance and potential of new technologies on the use of tissue culture in cropping, virus management, breeding, and biotechnology. Representatives from China, the Philippines, Malaysia and Australia gave pre-

![Banana exhibition at Queen Sirikit’s National Convention Center.](image1)

![INIBAP products proved popular during the symposium.](image2)

a, b & c. Winning entries in the banana competition were on display. Moto Ebanga from CRBP (center) was winner of the “most original banana prize.”
Banana Symposium in Thailand

Thai lady demonstrates production of banana sweets.

Banana products enter for the competition.
sentations on the banana production and trade in their respective countries. The impressive scale of the events in Thailand provided a magnificent context to celebrate and reflect upon the 15 eventful years since INIBAP was launched.

Tenth meeting of the Regional Advisory Committee of INIBAP-ASPNET
The 10th meeting of the ASPNET Steering Committee took place on 10-11 November in Bangkok, Thailand. The conference was hosted by Prof. Sujin Jinahyon, President of Naresuan University and Dr Ananta Dalodom, Director General of the Department of Agriculture (DOA/Thailand). Dr Emile Frison was Guest of Honor. Special guests from QUT, IITA, KUL, and CIRAD presented technical papers on Advances of Biotechnology R & D in Musa, Appli-
cation of Biotechnology in Banana Virology, Status of Banana and Plantain Breeding, Recent Developments in Musa Nematology Research, Study of Mycosphaerella fijiensis, Populations and Partial Resistance of Bananas and Status of Banana Weevil R & D.

Dr Agustin Molina, Regional Coordinator for Asia and the Pacific presented the highlights of the 10th year of ASPNET operations. Updates were provided on Banana R & D Activities in the Philippines, Nematology Research in Vietnam the ICAR/NRCB-INIBAP Project in India, the Evaluation and Adoption of the INIBAP hybrids at the Secretariat of the Pacific Community, Varietal Evaluation and Disease Management in Sri Lanka and the news of a promising clone in Taiwan which attracted much interest.

IMTP and NEP activities, the proposed National Repository Multiplication Distribution Center, the Musa Breeding Programme and the various activities and collaborations in ASPNET were discussed in the Planning Session. INIBAP staff, Dr Escalant and Ms Sharrock discussed with the Committee the two classifications of involvement in IMTP III: Performance evaluation sites (minimum requirement of 10 accessions) and In-depth sites (full spectrum of materials). A preliminary survey was carried out on the involvement of the various countries represented at the meeting. The participation of the private sector in trials was also considered. The possibility of incorporating an IMTP working group into PROMUSA was also brought up. A workshop may be conducted in order to standardize formats and data-gathering.

Dr Molina presented information on the proposed National Repository, Multiplication, and Distribution Center. According to the plan, the national government would assign an institution responsible for acquisition of materials from ICT, multiplication and distribution within the country. Some members said that such a set-up is already existing in their country and that it is multiplication and distribution which requires enhancing. Funding may be sought for countries who need assistance in this area.

An update on the status of RISBAP was presented by Ms Roa. Australia, Philippines, Sri Lanka, and Taiwan are active contributors to the database. Special mention was given to Australia for their campaign to raise awareness of the INIBAP databases. It was also reported that an LOA with Malaysia exists to provide assistance in data-gathering.

Finally, clarification was requested on the responsibilities of the members of the steering committee. After some deliberation, it was agreed that a small committee be formed to come up with a list which will be circulated for comments and then submitted to the regional coordinator.

During the meeting, Prof. Det Wattanachaiyongcharoen was elected Chairman of ASPNET steering committee, replacing Dr Chen Houbin of the South China Agricultural University (SCAU), who has served as Chair since November 1999. Prof. Wattanachaiyongcharoen will serve as Chair until the 11th ASPNET meeting which will be held in Sri Lanka in August 2001.

The Pisang Raja awards
In recognition of 21 years of outstanding accomplishment in banana breeding and biotechnology, and also for his profound contribution to INIBAP and ASPNET, Rony Swennen received the Pisang Raja award at the meeting of the ASPNET Steering Committee. Likewise the award was given to Dr Chamas Silaya for her immense contribution to banana research and development, including the authoring of over 20 technical articles and books in the area of banana taxonomy, genetics, and breeding, and her long association with INIBAP and its activities since 1986.

Addressing banana virus disease management in Bangladesh
Banana diseases are a major constraint of banana production in Bangladesh. Viruses, such as BBTV, BBrMV, BSV and CMV are a particular concern. In an effort to address the problem INIBAP sponsored a seminar-workshop on banana diseases and a virus-indexing training course. The events took place at the Horticulture Research Centre, Bangladesh Agricultural Research Institute (HRC-BARI), Joydebpur, Bangladesh, in September. They represented the third in a series of seminar-workshop and training sessions organized by ASPNET, the other two having taken place in the Philippines and Sri Lanka.

A total of 52 participants attended the workshop with speakers coming from Taiwan, the Philippines and Bangladesh. The nature, epidemiology and management of major banana pests and diseases were discussed. Emphasis was made of the successful use of virus-indexed tissue culture in the management of virus diseases. The Director General of BARI, Dr M.A. Razzaque, expressed his appreciation to INIBAP, ASPNET and Prof. Hong-Ji Su of the National Taiwan University, for their assistance in alleviating pest and disease problems in Bangladesh. He declared that a virus management programme will be implemented. Hands-on training, conducted by Prof. Hong-Ji Su, was provided for nine BARI scientific officers. Two indexing procedures, the ELISA and PCR-based techniques were taught.

Novel approaches to the improvement of banana production in Eastern Africa
Over the past two decades banana yields in East Africa have been declining. The most probable causes are the increasing load of pests and diseases (esp. black Sigatoka, nematodes and weevils) and the deteriorating natural resource base. The effort to produce improved varieties with locally acceptable post-harvest characteristics using conventional approaches is constrained by the high level of sterility of most East African Highland banana (EAHB) varieties. However genetic engineering technologies offer an alternative route for improving yields.

The Ugandan government is funding a project on “Novel Approaches to the improvement of banana production in Eastern Africa—the application of biotechnological methodologies” as their contribution to the CGIAR. It involves the collaboration of IITA, NARO, Makerere University, CIRAD, KUL and INIBAP, which will coordinate and supervise.

This project has a specific focus on improving the production of existing banana varieties by enhancing their resistance to fungal pathogens, nematodes and weevils, whilst maintaining their desirable post-harvest/culinary qualities. Complementary approaches will be used. In the case of black Sigatoka and nematode resistance, known genes coding for anti-fungal proteins and genes with a high potential to control nematodes will be introduced into EAHB cultivars by genetic transformation using a wide range of gene constructs. The most effective genes will be identified first in transgenic model plants and subsequently during field testing. Multiple resistance will be achieved by gene pyramiding.

In the case of weevil resistance two approaches will be followed. In collaboration with IITA and NARO, the genetic mechanisms underlying weevil resistance in EAHB will be studied and weevil resistance genes and genetic markers identified. At the same time, with CIRAD’s collaboration, toxins from the new strains of Bt, which have an effect on Coleoptera, will be tested for their...
efficacy in controlling weevils. Given the successful outcome of this phase of research, further funding will be sought to transfer weevil resistance into EAHB.

Developing a centre of biotechnology competence and upgrading existing molecular biology facilities in Uganda will form an essential element to the project. Ugandan scientists will receive training and their participation in international meetings and workshops will be supported.

A planning meeting and technical workshop took place in September in Uganda, bringing together all partners in the project. To develop plans for project implementation, four working groups on cell suspensions and tissue


demonstrated during the EXPO 2000 in Hanover, Germany (August 2000) and during the Banana and Pineapple professional meeting organized by CIRAD-FLHOR in Montpellier, France (September 2000).

Organized in seven chapters, this very attractive CD-ROM presents information on all the aspects of the crop lavishly illustrated with films, photographs, maps, comics, etc.

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All you want to know about
BANANAS
on a multimedia CD-ROM

This multimedia CD-ROM on bananas has been produced as a joint effort of the International Network for the Improvement of Bananas and Plantain (INIBAP) and the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD).

Demonstrated during the EXPO 2000 in Hanover, Germany (August 2000) and during the Banana and Pineapple professional meeting organized by CIRAD-FLHOR in Montpellier, France (September 2000).

- The world’s largest herb
- The much-travelled banana
- Banana – a basic food
- The industrial chain of dessert banana
- Watch that plant grow!
- Protecting the banana and its future
- Banana as veg or as dessert?

Participants in the project on “Novel approaches to the improvement of banana production in Eastern Africa – the application of biotechnological methodologies.”
culture, molecular research, germplasm evaluation, and weevil re-
search were formed. Each produced a detailed action plan for their activity,
clearly identifying the responsibilities of each partner. Visits were made to
the biotechnology laboratories of Makerere University, the NARO station
at Kawanda and to IITA's station at Na-
mulone to review the available facili-
ties. Recruitment process is now in
motion. Ph.D students to work on the
project are being identified and plant-
ing has started in the field. By January
2001 the project will be fully opera-
tional.

INIBAP web site
The traffic on the INIBAP web site has
doubled since June. Nearly 100 visits
are made daily, each taking an
average of more than three minutes on
the site. The databases and publica-
tions are amongst the most popular
parts of the web site. Shortly to be
launched are new sites for the regional
networks, MUSACO in West and Central
Africa, BARNESA in Eastern and Southern Africa, MUSALAC in Latin
America and the Caribbean and ASPNET
in Asia and the Pacific. These will
include more detailed information on
the activities, objectives and make up
of the networks, as well as statistics
highlighting the importance of banana
and plantain in these areas. It is now
possible to download from the web the
last INFOUSA (Vol. 9, 1), proced-
ings of the meeting on "Bananas and
food security", "Organic/environment-
tally friendly banana production"
(Spanish version) and "Organic ba-
nanas 2000: Towards an organic ba-
nana initiative in the Caribbean". Also
the one-off publications of Paul Allen's
catalogue of wild and cultivated ba-
nanas and the results of Phase II of
IMTP, "Evaluating bananas: a global
partnership", are available. Finally, the
INIBAP genebank web site has taken
on the INIBAP look and can be ac-
cessed at http://www.agr.kuleuven.
ac.be/dtp/tro/itc.htm.

Joint initiative between
IITA and INIBAP
The two Future Harvest centres car-
ying out Musa research and develop-
ment (IITA and IPGRI, through INIBAP)
recently decided to integrate their
Musa-related activities in Africa. The
agreement to establish a joint pro-
grame for Musa in Africa was final-
zeed at a meeting held in Uganda in
September 2000.

Although IITA and INIBAP were al-
ready working closely together in
Africa, they believed that their comple-
mentary programmes should be com-
bined into a single, well-focused re-
search effort. It was felt that in this
way, the impact of their programmes on
improving smallholder production of
Musa in Africa would be maximized.
The new joint programme will be imple-
mented in the framework of the two
sub-regional NARS-led banana research
networks—BARNESA operating under
ASARECA, and MUSACO operating under
WECARD/CORAF.

Strategic planning
Annual programme planning will be
carried out on the occasion of the BAR-
NESA and MUSACO Steering Commit-
tee meetings. These will provide a
forum for the stakeholders to discuss
the full research agenda and all issues
related to Musa in each sub-region.
These meetings will provide an opportu-
nity for priorities to be set and for the
roles and responsibilities of the various
players in the research agenda to be
clearly identified.

Germplasm conservation
IITA and INIBAP will take on joint re-
sponsibility for ensuring the long-term
conservation of Musa germplasm of
African origin. This will include the des-
nication of germplasm to the 'in trust'
collection held under the auspices of
FAO, ensuring the safety duplication of
all such conserved germplasm and mak-
ing information on germplasm available
through the SINGER database.

Germplasm evaluation
In the area of germplasm evaluation,
IITA and INIBAP have clearly com-
plementary roles. Thus IITA will continue
to focus on early evaluation of breeding
lines in multilocal tests, while INI-
BAP will focus on more in-field trials
in the framework of the International
Musa Testing Programme (IMTP).

Information
The MusAfrica newsletter, previously
published by IITA, will become a joint
IITA-INIBAP publication. The newslet-
ter will continue to be a forum for mem-
bers of the regional networks to ex-
change information on Musa research
in the region. Furthermore, activities
carried out in the framework of the joint
programme will be reported by
both INIBAP and IITA in their respec-
tive Annual Reports.

Public awareness
INIBAP and IITA will join forces in rais-
ing the awareness of policy makers and
the public, which it is hoped will lead to
the allocation of greater resources to
Musa research and development in the
region.

Staff at INIBAP
Alberto Vilarinhos
In the framework of the Advanced
Platform of Agropolis in Montpellier, a
joint project be-
tween INIBAP and
CIRAD has been
initiated with
funding from the French
Government. Al-
berto Vilarinhos,
a scientist with
experience in
molecular tech-
niques and the
genetics of banana from EMBRAPA in
Brazil, will carry out the research over
four years as part of his Ph.D. Entitled
the "Mapping of the Musa acuminata
translocation break points through
molecular cytogenetics", the project
aims to use new methods developed for
animals and also wheat and rye, to
demonstrate the position where segments
of DNA, known as translocations, break
off in the chromosomes. This will help
answer questions on segregation pat-
terns and facilitate genetic mapping
and ultimately banana breeding. Al-
berto has moved to France with his
family and started work in September.

Gaston Boussou
Gaston Boussou has taken up a tempo-
rary position as MGIS database assis-
tant. He will be
updating the
MGIS database in
preparation for
the publication of
the second Musa-
logue. He comes
to INIBAP with a
master degree in
information and
documentation
from the Univer-
sity of Montpellier, as well as various
qualifications in mapping and water
management and quality, and also biol-
ogy. His previous experience has in-
cluded work with the Agritrop database
at CIRAD and also supplying bibli-
ographic information for MUSALIT, also
at CIRAD.

Stijn Messiaen
Stijn Messiaen has been working on
secondment from INIBAP at the Ny-
ome, Cameroon-based Centre de
recherches regionales sur bananiers
et plantains (CRBP) since July 1998
as a Vlaamse Vereniging voor Ontwik-
elingsaanwerking en Technische
We wish Stijn success in his plans to and Dr Dirk De Waele of KUL, Belgium. Dr Cliff Gold of IITA, Kampala, Uganda Stijn's work at CRBP with inputs from CRBP . Dr Roger Fogain supervised of university students on attachment at CRBP. In addition to his research, and has many more manuscripts in the pipeline. In addition to his research, Stijn also participated in the training of university students on attachment at CRBP. Dr Roger Fogain supervised Stijn's work at CRBP with inputs from Dr Cliff Gold of IITA, Kampala, Uganda and Dr Dirk De Waele of KUL, Belgium. We wish Stijn success in his plans to pursue a PhD degree at KUL in his home country Belgium.

Julie Schurgers
Julie Schurgers worked as an INIBAP intern at CRBP from November 1998 to July 2000. She was part of the team that initiated research on cell suspensions and somatic embryogenesis at CRBP. For a time Julie coordinated research into rooted plantlets and proliferating cultures from the INIBAP-mandated regional germplasm distribution centre for West and Central Africa. Julie spent her last 7 months studying techniques employed to breed for resistance to nematodes at the Laboratory of tropical crop husbandry at KUL, Belgium under Prof. Dirk De Waele. We wish her well in her future endeavours back home in Belgium.

Books, etc...

**Banana cultivar names and synonyms in Southeast Asia**
The Southeast Asia region harbours the greatest wealth of banana diversity, both in wild and cultivated forms. This includes some of the rarest varieties in the world. But how to classify them and even what to call them has always been a complicated issue. In many cases, the same varieties have been given different names in different areas and the likewise the same name has been given to different varieties.

In September 1999 a landmark meeting of the curators of national banana germplasm collections took place in the Philippines. They resolved the names of nearly 300 banana varieties and agreed on a classification system, following that of Cheeseman and the International Code of Nomenclature for Cultivated Plants. This 24-page booklet provides the background on the nomenclature and classification of bananas in the region and the final listing of variety names and synonyms agreed at the meeting in Southeast Asia. An essential companion for collectors, curators, breeders and researchers around the world!

Available from the INIBAP regional office for Asia and the Pacific, c/o IRRI Collaborators Center, College, Laguna 4031, Philippines.

**Managing banana and citrus diseases**
*Proceedings of a regional workshop on disease management of banana and citrus through the use of disease-free planting materials held in Davao City, Philippines, 14-16 October 1998* Edited by A.B. Molina, V.N. Roa, J. Bay-Petersen, A.T. Carpio and J.E.A. Joven
ISBN: 971-91751-1-7

For the first time the proceedings of the meeting of the ASPNET Regional Advisory Committee are published in the form of a book of 154 pages. This publication presents the latest news on Musa research, development and future prospects from Malaysia, Indonesia, the Pacific Islands, Sri Lanka, Bangladesh, the Philippines and more in depth account from China. It also provides updates on the state of banana cultivar names and synonyms in Southeast Asia, the results of studies on nematode on the most common banana cultivars in Vietnam, the biodiversity of wild Citrus and banana are major cash crops for farmers in Southeast Asia. However both are experiencing dramatic declines in yield because of disease. The infections are so widespread that even nursery stock and parent trees generally used to replant diseased plantations are infected, and disease-free material must be sought from further afield. Advances in managing diseases of both Citrus and banana have involved developing new ways to efficiently produce and distribute uninfected seedlings, and of more sensitive ways to detect infections,
which may frequently be latent or symptom-less. In the case of bananas disease-free material is obtained through tissue culture. For Citrus certified disease-free seedlings from disease-free nurseries are being promoted. In either case the lessons learnt in developing such integrated disease management programmes are valuable to farmers of all types of crop.

The workshop on “Managing banana and Citrus diseases”, jointly organised by INIBAP and the Food and Fertilizer Technology Center, based in Taiwan, brought together researchers at the forefront of the battle against banana and Citrus diseases in Southeast Asia. Their work on the epidemiology of viral diseases, their ecology, detection and methods of management for both bananas and Citrus is presented in this 164-page book. Results of studies on the epidemiology, characterization and management of bunchy top and viral streak viruses, in particular, are included. As are recommendations for research, development and policy resulting from this unique workshop.

The publication is available from the INIBAP regional office in the Philippines.

Organic banana 2000: towards an organic banana initiative in the Caribbean
Report of the International workshop on the production and marketing of organic bananas by smallholder farmers, 31 October-4 November 1999, Santo Domingo, Dominican Republic
Edited by M. Holderness, S. Sharrock, E. Frison and M. Kairo

Diversification has never been so important, as it is now for small-scale farmers competing in a free market economy. Countries of the Caribbean have recognised the niche in the market for organic bananas, the Dominican Republic currently being the largest exporter of organic bananas. This meeting, jointly run by INIBAP, CAB International and the Technical Centre for Agricultural and Rural Cooperation (CTA), provided a forum for discussion and information exchange for a wide range of interest groups, from farmers to retailers, with the aim of developing an initiative to support organic banana production and export in the Caribbean.

This 174-page report provides papers on the current status of banana production, particular the development of organic production, in the Caribbean, as well as in Central and South America and Cameroon, also the prospects of the North American and European market, aspects of quality assurance and certification, and production constraints. The results of working groups and the conclusions of the meeting are also included. In brief, this publication presents an important discussion of the latest issues surrounding organic production of bananas and lays down a comprehensive plan of action for the way forward.

Contact the Information/Communications Unit at INIBAP headquarters for a copy of the book.

IPM news : Biocontrol News and Information
ISSN: 0143-1404
The September 2000 issue of Biocontrol News and Information (Vol. 21, No. 3) published by CAB International has a strong banana flavour. Almost the whole issue of this newsletter is devoted to banana integrated pest management. Articles provide information about banana IPM research in Uganda, Brazil, Ghana, Peru, Cameroon, Guadeloupe, Australia and Costa Rica. While there is a focus in many countries on IPM for banana weevil and nematode control, other aspects of IPM are also covered. These include integrated management of banana diseases, management of banana streak disease, forecasting systems for reduced pesticide usage and non-chemical control methods for post harvest diseases.

There are two contributions from INIBAP staff. ‘IPM and INIBAP’ describes the importance of IPM in INIBAP’s activities and the contribution made by INIBAP to promoting IPM through workshops, publications, supporting research, and conserving and distributing germplasm. More specific involvement in different IPM strategies is summarised; work in Asia to develop virus control programmes, success in combating Blood disease in Indonesia, mobilizing IPM for sustainable production in Africa and on-farm testing of IPM in East Africa. ‘Integrated approach for weevil control in Cameroon’ outlines the diverse tests for IPM under way in Cameroon. Amongst the mechanisms under trial are neem and wood ash, entomopathogenic fungi, chemical insecticides, ramp and pheromone traps. CRBP is also incorporating weevil resistance in its breeding programme.

Internet Round-Up
In the latest edition of Biocontrol News and Information, to which INIBAP has contributed (see above), the ‘Internet Round-up’ section is devoted to web sites about bananas and pest control. With kind permission from the publishing editor their recommended sites are reproduced here:

The Consortium for International Crop Protection (CICP) site has compiled a list of Internet IPM resources on banana, covering a wide range of banana IPM issues, including biological control at: http://www.ippc.orst.edu/cicp/fruit/banana.html

INIBAP’s own homepage is recommended for information on pest management and good links at: http://www.inibap.org

The Department of Primary Industries, Queensland, produces DPI notes giving pest management advice, and practical information on managing various pest and disease problems in a range of crops, including bananas, which you can find from: http://www.dpi.qld.gov.au/dpionotes

Political issues concerning bananas, a section on organic bananas and a list of documents will be (it’s currently under construction) available online at Banana link at: http://www.geocities.com/NapaValley/1702/

The Australian Banana Growers Council (ABGC) gives details of current activities, research programmes and banana links at: http://www.abgc.org.au

Project reports and summaries are available online as part of the CGIAR’s Systemwide Programme for IPM: http://www.cgiar.org/sipm

The International Institute of Tropical Agriculture (IITA) is managing a project on ‘Improving plantain- and banana-based systems’, a summary of which is posted at: http://www.cgiar.org/spipm/dbase/projects/iitaipd.html

DFID’s Crop Protection Programme also has a summary of a project on development of nematode resistance in bananas and plantain at: http://www.netcom.net.uk/~nri/pccp/r639l.htm

Details of CABI Bioscience’s work on adapting novel techniques for detection
and characterization of fungi causing Fusarium wilt and Sigatoka leaf spots of banana and plantain at: http://www.cabi.org/bioscience/annualreport_projects_egham.html

Florida Entomologist has a paper on ‘Timing and distribution of attack by the banana weevil (Coleoptera: Curculionidae) in East African highland banana (Musa spp.)’ at: http://www.fcla.edu/FlaEnt/fe82p631.htm

There is a paper on the banana moth from Hort Digest at: http://www.hortdigest.com/archives/2-2000/bananamoth.htm

and another from Agropolis at http://www.agropolis.fr/actualiteevenements/lettre/spe1099gb/integraprotec.html

Internet Round-up is reproduced from Biocontrol News and Information with permission of CAB International. Biocontrol News and Information is available from CABI Bioscience, www.cabi.org.

MusaDoc CD-Rom

The second edition of the MusaDoc CD-Rom, MusaDoc 2000 is out! The up-to-date versions of the INIBAP databases, MUSALIT – containing abstracts and bibliographic records of publications on Musa, and BRIS – the database of banana researchers are available. As are all of the recent publications, including

the popular Banana brochure, new fact-sheets and publications from 2000, such as the 1999 Annual Report, ‘Banana cultivar names and synonyms’, ‘Evaluating bananas: a global partnership’ and ‘Bananas and food security’. The CD-Rom also gives an illustrated summary of the INIBAP’s activities. Now everyone can be connected even if they aren’t on the web.

Requests should be directed to the Information/Communications Unit at INIBAP headquarters.

IMTP 2000

The next in the CD-Rom production line, is the first cutting of the IMTP database! Soon to be made available on the web, IMTP 2000 is the first effort by INIBAP to make the entire results of IMTP phases I and II widely available in database form. The CD-Rom also contains copies of the technical guidelines and the publication ‘Evaluating bananas: a global partnership’ which gives comprehensive analysis of Phase II results. In addition it provides the catalogue of candidate and reference clones, including those now available for Phase III trials, and the material transfer agreement. In fact all of the tools needed to take part in IMTP Phase III are here.

Requests to for copies of the IMTP 2000 should be directed to the IMTP Coordinator at INIBAP headquarters.

Postharvest and plantain agroindustry in the coffee region of Colombia

Edited by D.G. Cayón Salinas, G.A. Giraldo Giraldo and M.I. Arcila Pulgarín
ISBN: 958-96885-0-0

This 265-pages book provides the results of the research on postharvest issue and the use of plantain by-products through the agreements signed between Corpoica, Universidad del Quindío, Comité de Cafeteros del Quindío and Colciencias. The first part of the document presents a technical review of the basic aspects of biochemical and physiological processes which regulate and control the postharvest of vegetable produce with emphasis on the climacteric fruits as plantain, and discusses the main technologies for the adaptation and transformation of the product. It also includes 20 scientific and technical articles generated through the research work on plantain postharvest made by different institutions from the central coffee zone of Colombia. This publication was possible due to the technical and financial support of the Asociación para la Investigación en Plátano – ASIPLAT, and of the institutions that participated in research.

To obtain copies of this book, please contact Gerardo Caón Salinas, Corpoica – Armenia. Avenida Bolívar Sector Regivit 28 Norte, Armenia, Quindío, Colombia. E-mail: corpoarm@armenia.multi.net.co. Price: US$10 plus handling and postage.
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Instructions to authors

Typescripts should be prepared in English, French or Spanish and submitted in duplicate to the Managing Editor. They should be double-spaced throughout. All pages (including tables, figures, legends and references) should be numbered consecutively and referred to by these numbers in the text. If the typescript was prepared on a computer, please send a copy on diskette (or by e-mail) along with the printed ones, indicating the name and version of the wordprocessor used.

• Abstracts: An abstract not exceeding 200-250 words should be sent in the same language as the typescript, as well as translations (including the title) into the two other languages, if this is possible.

• Acronyms: These should be written in full the first time they appear in the text, followed by the acronym in parenthesis.

• References: All literature references made in the text should be referred to by author(s) and year of publication (e.g.: Sarah et al. 1992, Rowe 1995). A list of references, in alphabetical order, should be provided at the end of the text. Please follow the style shown below:


• Tables: These should be numbered consecutively and referred to by these numbers in the text. Each table should include a title.

• Illustrations: These should be numbered consecutively and referred to by these numbers in the text. Each illustration should include a clear and simple caption.
  Graphs: provide the corresponding raw data with the graphs.
  Drawings: provide originals if this is possible.
  Black and white photographs: provide them on bright paper and with good contrast.
  Colour photographs: provide good quality proofs and films or original slides.

Note: When plant material used for the experiments reported originates or is registered in the INIBAP genebank, its accession number (ITC code) should be indicated within the text or in a tabular form.

Thank you in advance for following these instructions
This will facilitate and accelerate the editing work.
The following publications are available from headquarters:
bananas by smallholder farmers. 31 October-4 November 1999, Santo 
Domingo, Dominican Republic.
environmentally friendly banana production. Proceedings of a 
INIBAP/CRBP/CTA/CFF 1999. C. Picq, E. Fouré & E.A. Frison (eds). Bananas and 
food security/Les productions bananerières: un enjeu économique majeur pour 
la sécurité alimentaire. Proceedings of an International Symposium held in 
Douala, Cameroon, 10-14 November 1998.
work of Paul H. Allen: a catalogue of wild and cultivated bananas.
(eds). Mobilizing IPM for sustainable banana production in Africa. 
Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23- 
28 November 1998.
Report of the second Steering Committee meeting held at Douala, Cameroon, 
Report of the first Steering Committee meeting held at Douala, Cameroon, 
8-10 December 1997.
plant disease in Asia and the Pacific: an overview of the PROMUSA virology 
workgroup held in Montpellier, France, 19-21 January 1998.
INIBAP 1998. C. Picq (ed.). Segundo seminario/taller de la Red regional de 
información sobre banano y plátano de América Latina y el Caribe. San José, 
resistant banana, cooking banana and plants hybrids. INIBAP Technical 
Guidelines 4.
INIBAP 1998. G. Orjeda in collaboration with the PROMUSA working groups on 
Sigatoka and Fusarium. Evaluation of Musa germplasm for resistance to 
Sigatoka diseases and Fusarium wilt. INIBAP Technical Guidelines 3.
INIBAP/ACIAR 1997. E. Arnaud & J.P. Horry (eds). Musalogue, a catalogue of 
Routine Screening of Banana and Plantain Hybrids: Criteria and Methods. 
INIBAP Technical Guidelines 2.
INIBAP/CTA 1997. P.R. Speijer & D. De Waele. Screening of Musa Germplasm 
PROMUSA: A Global Programme for Musa Improvement. Proceedings of a 
meeting held in Gosier, Guadeloupe, March 5 and 9, 1997.
INIBAP/IPGRI/CIRAD. 1996. Descriptors for Banana (Musa spp.).

The following publications are available from Asia and the Pacific office:
O.C. Pascua & R.R.C. Espino. Banana cultivar names and synonyms in 
Southeast Asia.
INIBAP-ASPNET 2000. A.B. Molina & V.N. Roa (eds). Advancing banana and 
plantain R & D in Asia and the Pacific. Proceedings of the 9th INIBAP-
ASPNET Regional Advisory Committee meeting held at South China 
Agricultural University, Guangzhou, China, 2-5 November 1999.
and J.E.A. Joven (eds). Managing banana and citrus diseases. Proceedings of 
a regional workshop on disease management of banana and citrus through 
the use of disease-free planting materials held in Davao City, Philippines, 14- 
16 October 1998.
INIBAP/ASPNET 1999. V.N. Roa & A.B. Molina (eds). Minutes: Eighth meeting of 
INIBAP-ASPNET Regional Advisory Committee (RAC) hosted by the 
Queensland Horticulture Institute (DPI) in Brisbane, Australia, 21-23 
October 1998.
INIBAP/ASPNET 1998. Minutes: Seventh meeting of INIBAP/ASPNET Regional 
Advisory Committee (RAC) hosted by the Vietnam Agricultural Science 
INIBAP/ASPNET 1997. V.N. Roa & R.V. Valmayor (eds). Minutes: Sixth meeting of 
INIBAP/ASPNET Regional Advisory Committee (RAC) hosted by National 
Research Center on Banana (ICAR) in Tiruchirapalli, India, 26-28 September 
1996.
Regional Information System for Banana and Plantain - Asia and the Pacific 
(RISBAP): Proceedings of a consultation/workshop held at Los Baños, 
Philippines, 1-3 April 1996. (ASPNET Book Series No. 6).
The Global Programme for Musa Improvement (PROMUSA) is a broad-based programme which aims at involving all the major players in Musa improvement. It was developed as a means to link the work carried out towards addressing the problems of export banana producers, with those initiatives directed towards improving banana and plantain production at the subsistence and smallholder level. The global programme builds upon existing achievements and is based upon ongoing research initiatives. PROMUSA is therefore a mechanism to further maximize the outputs and accelerate the impact of the overall Musa improvement effort. The programme is an innovative mechanism to bring together research carried out both within and outside the CGIAR, creating new partnerships between National Agricultural Research Systems (NARS) and research institutes in both developing and developed countries. The formation of such partnerships will also contribute to strengthening the capacity of NARS to conduct Musa-related research. The major thrust of PROMUSA is to develop a wide range of improved banana varieties from which growers worldwide can select those most suited to their needs. The programme brings together conventional breeding based on hybridization techniques with genetic engineering and biotechnological breeding approaches. This broad-based genetic improvement effort is supported by research being carried out on specific pests and diseases within the various PROMUSA working groups. An efficient mechanism for evaluating new varieties produced within the framework of PROMUSA is also an essential component of the programme.

What is PROMUSA?

The Global Programme for Musa Improvement (PROMUSA) is a broad-based programme which aims at involving all the major players in Musa improvement. It was developed as a means to link the work carried out towards addressing the problems of export banana producers, with those initiatives directed towards improving banana and plantain production at the subsistence and smallholder level. The global programme builds upon existing achievements and is based upon ongoing research initiatives. PROMUSA is therefore a mechanism to further maximize the outputs and accelerate the impact of the overall Musa improvement effort. The programme is an innovative mechanism to bring together research carried out both within and outside the CGIAR, creating new partnerships between National Agricultural Research Systems (NARS) and research institutes in both developing and developed countries. The formation of such partnerships will also contribute to strengthening the capacity of NARS to conduct Musa-related research. The major thrust of PROMUSA is to develop a wide range of improved banana varieties from which growers worldwide can select those most suited to their needs. The programme brings together conventional breeding based on hybridization techniques with genetic engineering and biotechnological breeding approaches. This broad-based genetic improvement effort is supported by research being carried out on specific pests and diseases within the various PROMUSA working groups. An efficient mechanism for evaluating new varieties produced within the framework of PROMUSA is also an essential component of the programme.

Minutes of the second PROMUSA Steering Committee meeting
Bangkok, Thailand, 7 and 8 November 2000

Present: Emile Frison (INIBAP)—Chairperson, Abdou Tenkouano (IITA), Mary Wabule (NARS of East and Southern Africa), Luis Sequeira (ARIs of North America), Adiko Amoncho (NARS of West and Central Africa), Elizabeth Aitken (ARIs Australia-Pacific region), Philippe Lepoirve (ARIs of Europe), David Berroa (NARS of Latin America and Caribbean), Luc Sas (Chair, PROMUSA Support Group), Jean-Vincent Escalant (PROMUSA Secretary), Suzanne Sharrock (rapporteur). Observers: Clifford Gold (IITA), Eldad Karamura (INIBAP). Absent with apologies: P. Faylon (NARS of Asia and the Pacific).

Role of the Steering Committee

It was noted that this meeting should be considered the first official PRO-MUSA Steering Committee meeting, which consists of members who have been properly appointed by the various constituencies they are representing. The roles and responsibilities of the Steering Committee have been confirmed as published in the original PROMUSA publication. In the same way, the role of the Secretariat of PROMUSA has been confirmed as reporting to the Steering Committee.

Terms of office and attendance at meetings

It was felt important to have some continuity in the composition of the Steering Committee (SC) and it was therefore decided that the terms of office of SC members should be two years, renewable three times. It was suggested that the representation from IITA and IPGRI should be institutional rather than personal, so that the same person could serve longer than the normal maximum of 6 years. It was agreed that if a member is unable to attend any meeting, he/she should appoint an alternate to attend in their place.

Programme support group of PROMUSA

The role of the PROMUSA Support Group was explained to the Steering Committee. This is an informal group of donors and other stakeholders and meetings with them provide an opportunity to discuss banana issues and keep bananas on the agenda. However, the meetings are mainly for information exchange and usually there are no financial commitments made.
PRO MUSA project funding

It was noted that there seemed to be some confusion amongst PRO MUSA participants regarding the role of the PRO MUSA Secretariat and Steering Committee in the identification of project funding. It was agreed that there was a need to clarify that the main role of PRO MUSA is to facilitate collaboration and partnerships, and not to provide funds. It was also agreed that the Secretariat could help participants develop project proposals upon request. With regard to projects being developed in the framework of PRO MUSA, it was felt that these should not be routinely evaluated by the Steering Committee, as this would add another layer of bureaucracy into the project development process.

Reporting on PRO MUSA activities

Reporting to the Steering Committee

It was noted that during the opening session of the PRO MUSA meeting, some of the reports provided by the working group convenors were very general and not sufficiently focused on progress in the last two years. The PRO MUSA Secretary reported that the working group convenors had experienced difficulties in obtaining feedback from the working group members and that generally over the last two years, the convenors of the working groups had not been playing a sufficiently active role. In this respect it was felt that the role of the convener had not been made sufficiently clear and it was noted that the working groups at this meeting were discussing this issue. With regard to reporting, it was agreed that the Secretariat should report to the Steering Committee every six months. Requesting the working group convenors to report to the Secretariat at a similar frequency would facilitate this.

Inter-group contacts

It was agreed that greater efforts are required to ensure better interactions between working groups. In this respect, it was agreed that a ‘convenors committee’ be established to bring together the convenors of each working group. This committee should meet formally prior to each global PRO MUSA meeting. Further informal contacts between the convenors should also be encouraged.

Feedback from regional networks

The Steering Committee agreed that the PRO MUSA Secretariat should be proactive in ensuring information exchange between PRO MUSA and the regional networks. This is to ensure that PRO MUSA really is addressing the needs at a regional level.

Financing for PRO MUSA

It was emphasized that PRO MUSA was not set up with the intention that it should become a funding mechanism, however, it was also noted that the operation of the programme does require financial support and such funds need to be identified. In this respect, it seems unlikely that sufficient funding from donors will become available in the near future.

The Steering Committee agreed that participants in PRO MUSA should have a stake in the funding of the programme, through, for example, covering their costs of participating in meetings. It was felt that the willingness of participants to cover such costs would also help to demonstrate to potential donors the value of the programme. It was noted that some participants did indeed cover their own costs for this and previous meetings. It was agreed that large projects developed in the framework of PRO MUSA could include meeting costs in the project budget.

In the area of funding, it was agreed that all Steering Committee members should make efforts to follow up on contacts with donors and in this way assist in the search for financial support for PRO MUSA. In this
Meetings of PROMUSA

It was noted that the International symposium on molecular and cellular biology on banana which will take place every two years, would be an appropriate event with which to link PROMUSA global meetings. The costs of holding global meetings were discussed, and it was suggested that efforts be made to approach foundations and private companies for support for future meetings.

It was suggested that linking future PROMUSA meetings with relevant symposia would facilitate the identification of funding by participants through travel grants to participate in scientific meetings etc. A further advantage of such linkages would also be in helping to ensure that PROMUSA participants are aware of the latest research results being presented at the symposium.

New initiatives under the umbrella of PROMUSA

Banana Genomics Consortium

The PROMUSA Secretariat provided a report to the Steering Committee on the Banana Genomics Consortium. This consortium was set up in Montpellier earlier this year to allow the development of Musa genomics ‘master plan’ with the free exchange of information between consortium members, but a limit on the exchange of information outside the consortium. The aim of the consortium is to focus on pre-competitive research and all results from research carried out by consortium members will be made freely available. The consortium has requested the Steering Committee of PROMUSA to endorse its operation in the framework of PROMUSA. It was explained that this consortium has its own ‘Scientific Committee’ and there is some degree of confidentiality regarding the development of its activities. The members of the consortium are all members of the PROMUSA Genetic improvement working group. The Steering Committee members agreed that the consortium is focusing on the genetic improvement of Musa and that its aims and objectives coincide with those of PROMUSA. It was agreed that this consortium provides a mechanism for researchers to have some level of confidentiality around their work, while still following in the spirit of collaboration which is PROMUSA. It was therefore agreed that the Musa Genomics Consortium should operate under the umbrella of PROMUSA.

Banana weevils as a new PROMUSA priority

When PROMUSA was first established banana weevils were not considered to be a global production constraint and genetic improvement was
not considered the most appropriate technology for control of this pest. However in recent years this situation has changed. Breeding tools have developed considerably and sources of resistance to weevils have been identified. Thus breeding for weevil resistance, using both conventional and biotechnological approaches is now seen as a viable option. Therefore the PROMUSA Secretariat has received several requests that weevil resistance be put on the agenda of the Genetic Improvement working group and that a working group on weevils be formed.

Following some discussion, the Steering Committee agreed that an informal group on weevils should be established. This group should gather further information on what research is being done where and report back at the next Steering Committee meeting.

Latin American biotechnology network

Information was provided on a biotechnology network that has been established in Latin America in the framework of MUSALAC. This network has a focus on genetic transformation and molecular genetics. The Steering Committee agreed that the network should be encouraged to operate under the umbrella of PROMUSA in the framework of the Genetic improvement working group.

Public awareness

It was noted that PROMUSA participants attend a large number of meetings around the world. It was suggested that working groups develop the content of posters that can be used by members to present at meetings. The secretariat should provide support to the development of these posters.

Election of Chairperson

Emile Frison was unanimously re-elected as Chairperson for 2000/2001.

Secretariat

The Steering Committee confirmed that INIBAP should continue to provide the Secretariat for PROMUSA.

Frequency of Steering Committee meetings

It was confirmed that the Steering Committee should attempt to meet once per year. Additional ad hoc meetings could be called if necessary. The next Steering Committee meeting has to be defined.

Report of the PROMUSA Genetic improvement working group

Participants: Maria Elena Aguilar (CATIE, Costa Rica), Françoise Carroll (CIRAD, Guadeloupe), François Cote (CIRAD, France), James Dale (QUT, Australia), Jaroslav Dolezel (IEB, Zheceic), Antonio Figueira (CENA USP, Brasil), Rafael Gomez Kosky (IBP, Cuba), Peter Gresshoff (CRCTPP, Australia), Pat Heslop-Harrison (JIC, UK), Christophe Jenny (CIRAD, Guadeloupe), Dieter Kaemmer (Frankfurt Univ. Biocenter, Germany), Dale Krigsvold (FHIA, Honduras), Gomez Lim (CINVESTAV, Mexico), Do Nang Vinh (AGI, Viet-Nam), Sebastião de Oliveira e Silva (EMBRAPA, Brasil), Luis Pérez Vicente (INVIT, Cuba), Michael Pillay (IITA, Nigeria), Nicolas Roux (IAEA, Austria), Lazlo Sagi (KUL, Belgium), S. Sathiamoorthy (NRBC, India), Jorge Sandoval (CORBANA, Costa Rica), Ronny Swennen (KUL, Belgium), Abdou Tenkouano (IITA, Nigeria), Koji Tomekpe (CRBP, Cameroon), S. Uma (NRBC, India), PK. Valsalakumari (KAU, India).

Rapporteurs: Jaroslav Dolezel and S. Sathiamoorthy.

Administrative and general matters

S. Sathiamoorthy (NRBC) and J. Dolezel (IEB) were appointed convenors for the group. S. Sathiamoorthy will be responsible for the Breeding and genetics sub-group while J. Dolezel will be responsible for the Genetic engineering sub-group.

The working group discussed the problem of insufficient funding for Musa research given the global importance of banana and plantain. Development genomics research, which has the potential to impact on all areas of Musa improvement, will not be feasible without considerable investment. The group also agreed that as part of its role PROMUSA should:

- Assist in setting global priorities for research and improvement
- Be a platform for communication/interaction
- Be a depository of information and assist in its distribution (new publications, tools, materials)
- Organize meetings—the global PROMUSA meetings and specialized satellite meetings
- Identify and contact potential donors
- Screen calls for project proposals and distribute the information
- Assist in project preparation.

The working group agreed that as part of their role, convenors should:

- Prepare agenda for group meetings
- Lead discussions during the meetings
- Stimulate the interaction between group members in between the meetings
- Accompany PROMUSA secretary to meet potential donors.

The large size of the group and the extensive discussions did not allow for the presentation of scientific reports nor for discussions with other working groups. Splitting the Genetic improvement working group into two smaller groups on breeding/genetics (which should maintain the status of a core PROMUSA group) and a biotechnology/genomics group should be considered.

Breeding and genetics sub-group

Research priorities of the Breeding and genetics subgroup were identified as follows:
• Establishment of a regional collaborative programme for Musa
  Improvement in Asia, the major centre of origin and diversity of
  the crop
• Prospecting for new wild /landraces types through explorations in areas of
  natural diversity especially in South and Southeast Asia
• Characterization and evaluation of varieties for new sources of
  resistance to major pests and diseases; Sigatoka, nematodes,
  Fusarium wilt and weevils (corm and stem weevils)
• Compilation of information on existing global Musa
  genetic diversity
• Emphasis on strengthening of diploid breeding for developing new breeding
  stock using classical and biotechnological tools
• Widening of genetic base using conventional and biotechnological
  approaches.

Genetic engineering
sub-group
Within the Genetic engineering sub-group, it was agreed that there was no
need to change overall priorities and strategies as established during the
previous two PROMUSA meetings. However, it was noted that there is an
increasingly urgent need to stimulate the development of Musa genomics
and that this target should be given the highest priority. The Banana Ge-
nomic Consortium, which was established within the PROMUSA initiative
in April 2000 may play a leading role. Members of the working group were
also briefed about the establishment of a Musa Biotechnology network in
Latin America. The possibility to establish closer links between them
should be considered.

Tissue and cell cultures
in vitro
A methodology for the establishment and maintenance of embryogenic cell
suspension cultures has been developed and is being transferred to various
laboratories. Embryogenic cultures are considered suitable experimental
material for genetic transformation, mutagenesis, and protoplast isolation in Musa. The
major constraint is the genetic instability of the suspension cultured cells and field-testing of regenerated
plants has been strongly recommended. While studying the nature
and mechanisms of genetic variation
in vitro is considered unrealistic, there is an urgent need to isolate markers for at least some of the most
frequent off types regenerated from suspension cultures. The markers
would be invaluable for early screening and might be also useful in opti-
mising culture conditions to reduce genetic instability. Tissue culture
should also be considered as a tool for the delivery of improved hybrids,
virus eradication and for long-term conservation via cryopreservation.

Genetic transformation
Significant progress has been made in the development of efficient transformation
systems for Musa. The technology is being transferred to various
laboratories and transgenic banana plants have been obtained in at least
five public laboratories. Generally, Agrobacterium-based protocols are
preferred over biolistic approaches as they are more effective, result in lower
number of integrated copies and lower frequency of transgene silencing.
While most of the current projects are focused on transformation of existing
cultivars, it has been proposed to extend the technology to diploid parents
and landraces, and incorporate transgenic plants in existing breeding pro-
grames. Major constraints involve the selection systems based on resist-
ance to herbicides and antibiotics, which may have a negative impact on
the public acceptance of transgenic bananas and plantains. There is a
general interest to collaborate in biosafety issues as well as in the use of embryogenic cell suspension cul-
tures for transformation. On the other hand, limited collaboration has been
foreseen in the area of promoters and vectors, namely due to potential prob-
lems with intellectual property rights.

Mutagenesis
Physical mutagenesis, namely gamma irradiation, has been successfully
used in some research projects and several clones with agriculturally inter-
esting traits (earliness, reduced
height, disease resistance, increased
yield) were reported. Major constraints include the problems with chimerism and the need to screen large popula-
tions of plants. In vitro systems for rapid dissociation of chimeras as well
as systems for early screening of de-
sired characters are urgently needed.
While most of the current projects are
focused on mutation induction in exist-
ing triploid cultivars, it has been pro-
posed to generate more mutants in
diploid parents and landraces. In addi-
tion to gamma irradiation, fast neutron
irradiation should be employed. More-
ever, the use of chemical and inser-
tional mutagenesis should be consid-
ered as alternatives to irradiation.
Mutagenesis is considered an attract-
tive tool to obtain plants with traits
which are not available in nature. It is
expected that mutagenesis will play
an increasingly important role in Musa
genome mapping projects, where it
will be used to generate deletion
stocks and knockout mutants.

Cytogenetics
Significant progress has been made in the area of Musa cytogenetics. DNA flow
cytometry became a widely accepted method for rapid ploidy screening and the methodology has
been transferred to two breeding sta-
tions. The method has also been
used to verify ploidy levels of acces-
sions held at the INIBAP Transit
Centre at Leuven. Given the relatively
high proportion of accessions where
the ploidy level was not confirmed
(9%), the analysis of other collec-
tions is strongly recommended. More
recent results indicate the suitability
of flow cytometry for rapid estimation of genomic constitution in unknown accessions and hybrids as well as for detection of aneuploidy. Two laboratories (IAEA, IEB) provide the service for institutions, which lack the necessary equipment. Methods in molecular cytogenetics (fluorescence in situ hybridization—FISH, genomic in situ hybridization—GISH) have been developed. FISH has been used to analyse the structure of Musa chromosomes at the molecular level, including the genomic distribution of mobile genetic elements and BSV integrants. GISH has been extremely useful in determining genomic constitution in hybrids. Detailed characterization of the Musa karyotype, including the identification of individual chromosomes and detection of chromosome structural rearrangement will be a priority of Musa cytogenetics in the near future.

Aneuploidy
Aneuploidy may become an important tool in Musa genetic studies. Recent results indicate a possibility to generate large numbers of aneuploids (mostly hypoploid via the loss of one or more chromosomes). Aneuploids have been obtained after regeneration from embryogenic cell suspension cultures, after irradiation and after a treatment with mitotic spindle poisons. DNA flow cytometry was found suitable for rapid detection of plants with aneuploid chromosome number. Once obtained, aneuploid plants may be maintained by vegetative propagation. Until now, aneuploids have been generated from triploid stocks. It has been proposed to generate and characterize a series of aneuploids from selected diploid genotypes.

Gene silencing and genome interaction
The phenomena of gene silencing and genome interaction should be intensively studied as they may have significant impact on current Musa improvement programmes. As most of the breeding programmes involve hybrid development, gene silencing and genome interaction may influence the characteristics of newly obtained materials. Alternation of gene expression may be an important mechanism for generating genetic variability in vitro while gene silencing may alter the expression of transgenes. Recent results indicate involvement of the A genome of Musa in the activation of BSV sequences integrated into the B genome. The understanding of underlying mechanisms might provide tools to develop materials resistant to BSV.

Genomics
Research in Musa genomics has been identified as the main priority for the group. Despite the importance of bananas and plantains, genomics studies in Musa are lagging behind other major crops. It is expected that the information derived from Musa genomic studies will help to create cultivars with optimal performance in different biological, ecological and cultural environments.

Genetic maps
There is an urgent need to develop a saturated genetic map of Musa. At present three mapping populations are available at CIRAD/CRBP, University of Queensland and IITA. A new segregation population is to be established by INIBAP. It has been recommended that molecular markers are exchanged between laboratories and that there is collaboration in increasing density of the maps. The work should be focused on the development of STMS (Sequence Tagged Microsatellite Site) markers which are locus-specific, co-dominant and highly polymorphic. Although the development of STMS markers is expensive, once established the methodology is easily transferable. The group also discussed a need to transfer mapping populations to other locations.

Physical maps
Physical maps and integrated genetic and physical maps are urgently needed for sequencing. An extensive list of resources, which will be required for physical mapping, includes BAC (Bacterial Artificial Chromosome) libraries, cDNA (complementary DNA) libraries and ESTs (Expressed Sequence Tags). Although there has been no strategic investment in Musa genomics during the last few years, some materials are already available. Two BAC libraries (Calcutta 4) are available (at cost) from Texas A&M University BAC Centre, new BAC libraries are being constructed by CIRAD, CICY and IEB, leaf cDNA library has been developed at CINVESTAV. Furthermore, Zenecca developed over 80,000 ESTs. While urgently required, physical mapping will demand considerable investment in terms of equipment, consumables and qualified personnel. At present, two laboratories (CIRAD, IEB) are equipped with robotic equipment suitable for construction and handling of DNA libraries and for preparation of DNA arrays, one laboratory (UL) is purchasing a microarrayer. To make the full use of currently available resources, it will be important to coordinate existing research efforts.

Gene discovery
While map-based gene cloning remains an attractive route for gene isolation, other approaches towards gene discovery should be considered in research projects. These include comparative genomics, differential screening and gene tagging.

Marker assisted breeding
Although attractive, marker assisted (MAS) breeding is still largely an aspiration for the future for Musa improvement. The reason being the delay in the development of Musa genomics, and the lack of suitable molecular markers linked to traits of interest, e.g. disease resistance and parthenocarpy. At present, only markers that
allow rapid detection of the presence of A and B genomes are available.

**Germplasm assessment (biodiversity)**

New materials obtained from exploratory missions as well as materials held at existing collections (especially those in Asia) should be extensively characterized at different levels (morphological, agronomic, molecular). The characterization should include determination of chromosome number, genome size and genomic constitution. Molecular markers (RFLP, STMS, CAPS, AFLP) are available for classification and identification of *Musa* germplasm. They have been used by CIRAD to characterize accessions held at the INIBAP Transit Centre in Leuven. The classification of a relatively high proportion of accessions was not confirmed (~10%), indicating a need to analyse other collections, too. The working group suggested that the evaluation of in vitro collections should include duplications in field conditions. It was also suggested that access to the MGIS database should be improved.

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**Report of the PROMUSA Sigatoka working group**

Participants: E. Aitken (CRC TPP, Australia), C. Abadie (CRBP/CIRAD, Cameroon), J.P. Busogoro (Univ. Gembloux, Belgium), J. Carlier (CIRAD, France), B. Fullerton (HortResearch, New Zealand), A. Gutierrez Rojas (CORPOICA, Colombia), M. Guzman (CORBANA, Costa Rica), Z. Jiang (SCAU, China), N. Masdek (MARDI, Malaysia), G. Molina (INIBAP), W. Tushemereirwe (NARO, Uganda), L. Perez Vicente (INISAV, Cuba), G. Rivas (CATIE, Costa Rica), R. Selvarajan (NRCB, India), B. Williams (QDPI, Australia).

Joint convenors: Jean Carlier and Bob Fullerton.

**Introduction**

At the beginning of the working group session, each participant briefly made a presentation of current developments in their research group. There followed a discussion on the identification and distribution of banana pathogens in Asia. The durability of resistance to diseases was also a major point of discussion. Participants were then allowed to review and update research priorities. These are given in detail below. The sources of information and comments are given in brackets in order to facilitate further exchanges within and between the working groups. Finally the opportunities provided by PROMUSA and suggested activities within the programme were discussed.

**Research priorities**

1. **Determine the distribution and relative incidences of** *M. eumusae*, *M. fijiensis* and *M. musicola* **in different countries of Southeast Asia.**

   Following the publication in Phytopathology (Carlier et al. 2000), Septoria Leaf Spot disease, has been adopted as the common name of the disease caused by *Mycosphaerella eumusae* (anamorph *Septoria eumusae*). This disease may have been previously observed in India (Dr Selvarajan, NRCB). A formal Latin de-
scription of Mycosphaerella eumusae will be published to establish it as a valid species (QDPI, CIRAD).

Today, the presence of the pathogen has been confirmed in southern India, Sri Lanka, Thailand, Malaysia, Mauritius, Reunion Island and Nigeria (CIRAD). Septoria leaf spot disease has not yet been recorded in China (Dr Jiang, SCAU).

The distribution and relative importance of the three different pathogens causing Sigatoka leaf spot-like diseases in Asia is widely unknown. In order to initiate investigations to answer such questions, a survey is ongoing in India (NRCB), Malaysia (MARDI), Sri Lanka (RARC), Philippines (IPB/UPLB) and China (SCAU). CIRAD is also supporting this project by defining protocols and carrying out complementary analysis of leaf samples. The survey should continue and expand into other Asian countries.

2. Develop appropriate diagnostic tools for the identification of Mycosphaerella leaf pathogens

To enable surveys of different Mycosphaerella species to be conducted, a training course in basic fungal identification using morphological characters is necessary. A manual with descriptions of symptoms and morphological characters of the different species would be very useful. The development of molecular methods to discriminate between the species is also essential for confirmation and for diagnosis of mixed infections or infections on old leaf material. Such a method has already been developed using restriction assay of PCR-amplified ITS regions of rDNA (Dr Carlier, CIRAD). However, this method requires the isolation and cloning of the fungi from leaf samples. A quick test for rapid local identification of the pathogens without isolation could be useful for analysis of numerous samples. The primers were defined in the ITS sequence for the detection of Mycosphaerella fijiensis and M. musicola (Johanson and Jeger 1993). However, these primers are not sufficiently specific to distinguish them from other Mycosphaerella species which may be isolated on banana leaves (10 Mycosphaerella or species belonging to related anamorph genera were detected—Dr Carlier, CIRAD).

3. Undertake a study of the basic biology of M. eumusae and the epidemiology of Septoria leaf spot

More knowledge is required on the life cycle, infection and sporulation conditions, relative importance of different spore types and response to different climatic conditions of M. eumusae and Septoria leaf spot disease.

4. Develop a detailed understanding of the population structures of Mycosphaerella fijiensis, M. musicola and M. eumusae

Studies of the population structures of M. fijiensis and M. musicola are in progress at continental, regional and local scales in Africa, Latin America/Caribbean, and Australia (CRBP, CATIE, CIRAD, CRCTPP, CORPOICA). Such studies should be extended, particularly to south and Southeast Asia. In India bananas are grown over a wide range of latitudes, altitudes and climatic zones and under varied farming systems. It is likely that over time considerable diversity has evolved within the populations of the different pathogens (Dr Selvarajan, NRCB). The studies of population structure should include both molecular and biological analyses. Population structures may be different under large-scale commercial systems compared to small plot systems because of different selection pressures (chemical vs. genotype). The sampling protocol and methodology should be shared and standardized to ensure that results from different laboratories can be compared.

5. Develop methods to follow the change in pathogen populations in response to selection pressure from new banana genotypes

It will be essential to monitor changes in pathogen populations in areas where new resistant hybrids are being grown on a large scale. Strategies to ensure durable resistance management may be defined on the basis of population structure analysis and epidemiological studies. Such strategies will certainly integrate the use of classic breeding and genetic transformation. A study is in progress in Cameroon (CRBP, CIRAD). This will enable the evaluation of a methodology which includes population structure and epidemiological analyses. Plot size and duration could be key factors in the study.

Several observations were reported that pathogen populations could evolve to overcome disease resistance. Yangambi km5 resistance to M. fijiensis has apparently been overcome in Cameroon (CRBP) and possibly in Cuba (Dr Perez Vicente, INISAV). Paksa resistance has been overcome in Polynesia (Dr Fullerton, HortResearch), possibly in Cuba (Dr Perez Vicente) and in China (Dr Jiang, SCAU). However, the identities of the clones should be checked. The resistance of some FHIA hybrids might also decline. There are reports of significant levels of disease in FHIA-01 in Pacific Islands, India and Australia (Dr Fullerton, HortResearch; Dr Selvarajan, NRCB; Dr Aitken, CRCTPP) and in FHIA-03 in Cuba (Dr Perez Vicente, INISAV). However, Sigatoka spots could exist on these hybrids because of high inoculum loads. Thus, changes in pathogen populations should be distinguished from particular epidemiological effects.

6. Identify new sources of resistance to banana leaf diseases

Current breeding programmes are relying on a very narrow genetic base for developing resistance (review by Dr Tenkouano, IITA). There is extensive genetic diversity in banana both between and within species in Asia. Investigations and evaluations of new material for resistance against the different leaf spot pathogens should be conducted in south and Southeast Asia. There has been extensive collecting already done in Vietnam and in other countries. Evaluations should be also carried out on existing collections. Such analyses will help estab-
lish the relationship between resistances to the different leaf spot pathogens. Evaluations should include information on the response of different banana varieties to these pathogens either from artificial or natural infections and epidemiological studies.

7. Develop a better understanding of the mechanisms of resistance, in particular partial resistance
Several ‘mechanisms’ of partial resistance to M. fijiensis have been reported and are being evaluated for relative efficiency in the control of the disease (CRBP, CIRAD). It is assumed that partial resistance is likely to be more durable than total resistance. The combination of different resistance mechanisms could improve chances of durability. Analysis for partial resistance in diploids is needed to introgress resistance into diploid improvement programs.

Some work has been done on mapping and identification of genes controlling resistance (CRBP, CIRAD, CORPOICA). This should be extended to allow the development of marker-assisted breeding systems and genetic transformation. Genetic and molecular studies of pathogenicity should be carried out concurrently.

The leaf pieces method, including methods for isolation, culture and inoculum production for the different pathogens (CIRAD), should be published and distributed to users. A first protocol has already been diffused. A standardized scale for recording levels of disease resistance will be developed for in vitro screening. The use of M. fijiensis toxins (or Juglone) may lead to a useful screening system (Dr Busogoro, Univ. of Gembloux), but the role of toxins and the mechanism of action in pathogenicity should be determined. Studies are also needed to establish whether toxins are involved in Septoria leaf spot.

**Other diseases and news**

**A new project**
CIRAD, in collaboration with NRCB, MARDI and NERI (Denmark) and with the help of INIBAP, submitted an INCO-DEV project to the European Community. Several of the priorities listed above constituted the objectives of the project. If it is accepted, it will initiate important collaborative work in India and Malaysia. Additional funds should be sought to extend studies to other Asian countries and to address additional priorities.

**Blood disease**
This fatal disease is caused by a strain of Ralstonia (Pseudomonas) solanacearum, which is closely related to the organism that causes Moko disease. The pathogen is carried in infected plant material, and possibly transmitted by flower feeding bats and insects. The disease has spread through Indonesia and West Papua, and recently was found in west PNG (Dr Williams, QDPI). All banana types seem to be susceptible, posing immediate implications for food security in PNG and the loss of germplasm diversity.

**Speckle Mycosphaerella spp.**
In most cases, this pathogen is regarded as of minor concern. However, its occurrence seems to be increasing in importance in hybrids. It is suspected that several species may cause the disease (Dr Carlier, CIRAD). These should be identified and their distribution established. The population structure, too, may need to be investigated. Detection of infection should be incorporated into screening programmes. For the present, information is only available from natural infections, and an artificial inoculation system should be developed.

**Freckle Phyloclista/Guignardia**
This disease is important in Malaysia and Philippines. Its relevance elsewhere in region is unknown.

**China**
A large number of diseases are reported from China (Dr Jiang, SCAU). Colletotrichum and Deightoniella can be very severe. Black Sigatoka is evident, but yellow Sigatoka is a more immediate concern. Septoria has not yet been recorded.

**Fungicide resistance**
Increasing resistance to fungicide has become a serious problem in most commercial areas. Resistance to benzimidazoles, triazoles and strobilurins, in particular, has been reported (Dr Guzman, CORBANA; Dr Abadie, CRBP). A search for effective alternatives is under way. Meanwhile, the incidence of growing fungicide-resistance stresses the need for a commercially acceptable disease-resistant banana.

**Sigatoka symposium**
The advantages of holding the PROMUSA meeting back to back with the Sigatoka symposium were discussed. Several meetings are proposed for Costa Rica and Cuba in 2001. The possibility of combining meetings is being investigated and the group will decide where the next PROMUSA meeting will be held.

**PROMUSA**
Participants felt that the principal advantages conveyed by PROMUSA are provided in the opportunities to attend the meetings, interact with other people with similar interests and to be updated on the incidence of and research on different diseases without having to wait for publication. This is particularly useful for people at the implementation level in the field, who are often working in isolation. The PROMUSA meeting allows them to understand priorities outside their immediate region. Information exchange is also seen as a very important function of PROMUSA and the fact that groups are able to decide how they communicate and interact.

The PROMUSA meetings should be used as a way to organize research and to be more efficient (i.e. by setting
priorities). A number of activities for PROMUSA were suggested:
• A database of organizations which may be prospective project partners should be created and maintained
• Meetings between prospective partners should be facilitated (including the funding or support for planning visits)
• A close contact should be established with funding agents with PROMUSA acting as a coordinating body, setting priorities and avoiding duplication
• Although PROMUSA is not seen to have a role in evaluating or refereeing project proposals, it could advise on the relevance of proposals in relation to overall priorities.

Report of the PROMUSA Fusarium wilt working group (FWWG)
Participants: Africano Kangire (KARI/NARO, Uganda), Altus Viljoen (FABI, South Africa), Aristoteles Pires de Matos (EMBRAPA/CNPMP, Brasil), Julio Hernandez (ICIA, Canary Islands), Mauricio Rivera (FHIÁ, Honduras), Mary Wabule (KARI, Kenya), Mike Rutherford (CABI, UK), Randy Ploetz (University of Florida, USA), Shin Chuan Hwang (TBRI, Taiwan), Suzy Bentley (CRCTPP, Australia) et Zaag de Beer (ITSC, South Africa). Apologies from: Ken Pegg (QDPI, Australia), Liew Kon Wui (Universiti Sains Malaysia), Mike Smith (QDPI, Australia) and Natalie Moore (QDPI, Australia).
Rapporteur: Suzy Bentley
Working group discussions covered four main areas:
• Key issues for disease management and current research priorities
• Interactions between FWWG and other working groups
• Feedback on PROMUSA
• Proposed communication strategy for FWWG.

Key issues for disease management and current research priorities
The key issues relating to the management of Fusarium wilt and current research priorities were developed at the FWWG meeting held on 21-22 October, 1999 in Kuala Lumpur, Malaysia (see PROMUSA No. 4, published in INFORMUSA Vol. 8, No. 2). These issues were:
1. Pathogen diversity
2. Disease management strategies
3. Epidemiology, and
4. Other research issues of current importance.
Progress in each of these areas was discussed and each issue was reviewed to prioritize the recommended action required and to update research priorities (Table 1).

Research priorities
The group identified the standardization and evaluation of the plantlet-screening test for Fusarium wilt resistance as the most important research priority. A standard protocol for resistance evaluation needs to be developed and assessed in different laboratories, and also made available to breeding programmes.
The development of a DNA-based diagnostic system for detection and identification of all races and strains of Fusarium oxysporum f.sp. cubense (Foc) directly from plant and soil was also considered a priority. A rapid
and accurate diagnostic test is necessary for the identification of disease outbreaks, identification/certification of clean planting material and research into the epidemiology and ecology of disease.

**Databases**

The establishment of a database containing a combined list of all of the isolates of *Foc* available through each of the major culture collections (CABI, UK; DPI, Australia; FABI, South Africa; ICIA, Canary Islands; KARI, Uganda; TBRI, Taiwan; UF, USA; and USM, Malaysia) was deemed useful. A bibliography of fusarium literature (in each of the key research areas listed above) and made available through

<table>
<thead>
<tr>
<th>Table 1. Priorities for Fusarium wilt disease management and research.</th>
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<tr>
<td><strong>Issue</strong></td>
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<tr>
<td>1. Pathogen diversity</td>
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<td>1.1 Genetic diversity</td>
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<td>1.2 Pathogenic diversity</td>
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<td>1.3 Diagnostics</td>
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<td>2. Disease management strategies</td>
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<td>2.1 Education and awareness</td>
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<td></td>
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<td>2.2 Quarantine measures to prevent pathogen spread</td>
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<td>2.3 Clean planting material</td>
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<td>2.4 Development of resistant varieties</td>
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<td>2.5 Adoption of disease resistant varieties</td>
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<td>2.6 Chemical/biological control</td>
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<td>2.7 Cultural control</td>
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<tr>
<td>3. Epidemiology</td>
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<td>Several research opportunities exist, including investigations into the temporal and spatial development of disease, focal development of disease, pathogen survival in infected plant material, soil and debris, and alternative host studies.</td>
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<tr>
<td>4. Other research issues</td>
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<td>4.1 Plantlet screening test</td>
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<td>4.2 Collect and evaluate native germplasm for reaction to <em>Foc</em></td>
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<td>4.3 False Panama disorder</td>
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the INIBAP Web site was also considered to be a useful resource.

**Interactions between FWWG and other working groups**

The following issues were considered to be a priority for interaction with other PROMUSA working groups:

**Genetic improvement working group**
- Identification of additional resistance in land races and hybrids
- Standardization and evaluation of the plantlet screening test
- Collate existing data for resistance of wild banana types in germplasm collections
- Obtain a better understanding of the mechanisms of resistance to Fusarium wilt
- Identification of markers for resistance to Fusarium wilt
- Establishment of a banana breeding programme in Asia.

**Nematology working group**
- Inform the Nematology working group of the developments within the Fusarium wilt plantlet-screening test. Combining/coordinate the Fusarium wilt plantlet-screening test with the nematode resistance test is a possibility.

**Feedback on PROMUSA**
- The structure of PROMUSA (the relationships among the working groups and between the working groups and the Steering Committee) was unclear to some, simple terms of reference covering the aims of the working groups within PROMUSA, the role of the secretariat and the role of the working group convenor may be useful.
- A review mechanism for the working groups and a procedure for nominating new working groups (e.g., Extension) was suggested.
- A more rigorous reporting system for the working groups, e.g., twice-yearly reporting against action items and milestones added to action items, was also suggested.

**Proposed communication strategy for FWWG**

It was proposed that better communication within the FWWG could be achieved by:
- Using the PROMUSA/FUS listserver
- Monthly research updates submitted by different FWWG members (distributed on the PROMUSA/FUS listserver) collated into a yearly newsletter (issued on the PROMUSA Web site).

It was proposed that the next Fusarium wilt working group meeting be hosted by Dr Altus Viljoen (FABI) in South Africa in 2002.

**Report of the PROMUSA**

**Nematology working group (NWG)**


**Research results**

Each members of the Nematology working group provided an outline of the results of nematology work in their research group. Since the last meeting in Cameroon (1998), research carried out may be classified into three main areas:

Biodiversity in nematode communities

Studies are ongoing on the interspecific and intraspecific diversity of *Radopholus similis* and *Pratylenchus coffeae* (Australia, Costa Rica, Vietnam, Cameroon and France). Field surveys can reveal the existence of secondary species, which may be a potential threat to banana production. For instance a new species, *R. musicola*, has been found in Australia. A total of 33 species in 18 genera have been identified in Cameroon, whilst surveys suggest that *R. similis* may be absent from banana plantations in the Vietnam. Meanwhile, using different molecular techniques, CIRAD has illustrated that *R. similis* populations may be divided into two genomic groups, one covering Cameroon, Costa Rica and Australia, the other extending from Côte d’Ivoire to Uganda.

**Impact of nematodes on bananas**

The correlation between root damage and yield loss is being studied in Costa Rica, Vietnam and Cameroon. Concern was expressed at the results of a recent survey, which indicated that most subsistence farmers in South Africa are using the same banana variety. What’s more, production in Mozambique, which represents an important source of material for South Africa banana growers, has plummeted.

**Screening, mechanisms of resistance, transformation**

Screening for resistance in banana varieties is occurring in numerous countries. In Vietnam recently collected varieties are being tested. In Uganda, a new screening technique has been devised using single root inoculation. *In vitro* screening is ongoing at KUL. Studies of phenolics and the histological morphology of roots are being carried out in India and Cameroon to investigate the mechanisms of nematode resistance, specifically in *Yangambi* km5. Meanwhile the use of model transgenic plants, e.g., *Arabidopsis*, in developing nematode resistance in bananas is being investigated at KUL.
Research priorities

A number of new research priorities were identified. Former priorities have been rearranged into three main axes:
- Nematode communities, including biodiversity
- Damage and yield loss potential of populations
- Resistance screening: methods, sources, mechanisms.

Link with Genetic improvement working group

NWG proposed a table displaying putative needs by plant breeders (Table 2). The first three columns represent different categories of work. The last column is the ‘offer’ of possible input by nematologists.

The role of the NWG and PROMUSA

Discussions were held on the functioning of the NWG and of PROMUSA as

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Table 2. Links with the Genetic improvement working group.

<table>
<thead>
<tr>
<th>What do plant breeders need from the NWG?</th>
<th>IPM</th>
<th>Classical</th>
<th>Molecular</th>
<th>Present knowledge</th>
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<td>&gt; Host status:</td>
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<td>• resistance</td>
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<td>• tolerance</td>
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<td>&gt; Sources of resistance (useful for breeding)</td>
<td>+++</td>
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<td>&gt; Mechanisms of resistance</td>
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<td>&gt; Genetic basis inheritability</td>
<td>++</td>
<td>++</td>
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<tr>
<td>&gt; Markers (molecular)</td>
<td>+++</td>
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<tr>
<td>&gt; Genes (proteins)</td>
<td>(+)</td>
<td>+++</td>
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</table>

| Tools                                    |     |           |           |                  |
|> In vitro screening                      | +++ | +++       |           | +                |
|> Greenhouse screening                    | +++ | +++       |           | +                |
|> Field screening                         | +++ | +++       |           | +                |
|> Highly sensitive screening              | +++ |           |           | -                |

Members of the Nematology working group.
a whole. Although the members of the NWG have been very active, there has not been much collaboration within the NWG nor between the NWG and the breeders. Communication obviously might be improved. Through discussions an attempt was made to address these problems and to define the current research priorities and needs for the forthcoming year.

The role of the convenor was debated. Dirk De Waele was chosen as the new convenor. The members agreed that the convenor alone cannot make the NWG function, all members have to participate and to be actively involved. They also agreed that the convenor should not cause a ‘bottleneck’ for communication externally (i.e. with the secretariat/board, others WG).

In the discourse on PROMUSA, conclusions were made that:

- PROMUSA should act as facilitator of communication (for people who are willing to communicate) and bring about better collaboration and the exchange of information.
- PROMUSA should be a facilitator for working groups in the access of funding (not providing funds itself) and enable better communication for project building. To contribute to PROMUSA, the NWG will:
  - improve communication by updating the mailing list, sharing information on the Internet (abstracts of publications, methodologies, overview of ongoing research), exchanging post-graduate students and research associates, exchanging ‘materials’, etc.
  - gather present knowledge and establish three databases: on nematode communities, biodiversity (J.-L. Sarah), damage and yield loss potential (R. Fogain), sources and mechanisms of resistance (D. De Waele)
  - participate in IMTP III by providing a list of 10 genotypes to be tested in different places (R. Swennen and all members), by sending information to the mailing list (allowing anyone with an interest to join) and through field trials (15 replications, using plants from naturally infested and nematicide-controlled fields)
  - plan a meeting to follow the Nematological Congress of NSSA (South Africa, May 2001)—‘Workshop on genetic improvement of Musa for nematode management’ (2-3 days).

Report of the PROMUSA Virology working group
Participants: Marie Line Caruana (CIRAD, France), James Dale (QUT, Australia), Martine Delanyo (Univ. of Gembloux, Belgium), Glyn Harper (JIC, UK), Bertrand Helliot (Agricultural University, Gembloux, Belgium), John Hu (Univ. of Hawaii, USA), Jackie Hughes (IITA, Nigeria), Roger Hull (JIC, UK), Lawrence Kenyon (NRI, UK), Phillipe Lepoivre (Univ. of Gembloux, Belgium), Ben Lockhart (Univ. of Minnesota, St. Paul, USA), Gerhard Pietersen (ARC-PPRI, South Africa), Helena Reichel (CIRAD, France), Martine Delanoy (Univ. of Gembloux, Belgium), Glyn Harper (CIRAD, France), James Dale (QUT, Australia).

Rapporteur: Jackie Hughes

BSV and other virus (potex) in germplasm movement and exchange

Discussions were held on the functioning of PROMUSA, of the Working Group and the function of the convenor. A new convenor was chosen, Jackie Hughes, and appreciation shown for the contribution of Roger Hull, the outgoing convenor. Presentations on the activities of the various research groups represented in the Working group were made on each virus. A detailed summary was made of the current diagnostics used at the INIBAP Virus indexing centres as well as those available to researchers and commercial organizations.

Banana bunchy top virus (BBTV)
Sequence variability of BBTV, particularly in Asia, was recognized to be wider than previously thought. According to symptom expression, different biological variants exist. Indicators for resistance in mature plants have been identified. Also a number of transgenic plants have been developed. At least one construct is proving to be resistant but not immune to the virus. The knowledge of the molecular biology of BBTV is well advanced and a range of microsatellite DNA sequences associated with Asian isolates are established.

Banana bract mosaic virus (BBMV), genus Potyvirus
Queensland University of Technology reported that Cavendish and Bluggoe varieties genetically modified with coat protein constructs of BBMV are now available for testing. Field-testing is planned in the Philippines. The sequencing of genes from different samples of the virus (including CP and Nib) has revealed no more than 5% genetic variation at the nucleotide level in CP and Nib. A construct has been developed with ‘average’ variation. Apart from known occurrences in the Philippines, India and Sri Lanka, the virus has been detected once in Western Samoa and rarely in Vietnam. These isolates, however, did not display typical symptoms.

Queensland Department of Primary Industry has identified a BBrMV isolate with more than 10% genetic variation, which is significant to the development of transgenic material. A complete range of serological and PCR-based diagnostics are available.

Cucumber mosaic virus (CMV)
Although CMV is widespread, it is not generally a serious disease. However with the rise in number of tissue-cultured plants in banana production in Taiwan and China, CMV is causing more problems. Mixed infections of CMV and banana mild mosaic virus can also produce more severe symptoms. CMV strains infecting banana have been characterized in Hawaii, Taiwan and China. Transgenic plants with resistance to CMV infection are under development.
**Banana mild mosaic virus (BanMMV)**

The Ducasse filamentous virus strain isolated from Pisang Awak (ABB) has been totally sequenced. It seems to be a new virus type between potex, fovea and alexiviruses.

The filamentous virus identified in co-infection with BanMMV is serologically related to the filamentous particle infecting a broad range of *Musa* germplasm, particularly cooking bananas, and 11% of the Guadeloupe CIRAD banana collection.

The primers defined from a conserved CP zone of Ducasse virus, and poly A, are used in order to study the diversity of the virus in this collection and in a part of the INIBAP germplasm. Because no, or only mild, symptoms are associated with this virus in single infection, no relevant information is available in terms of impact and epidemiology.

A joint proposal between Gembloux, CIRAD, CORPOICA and the University of Costa Rica, INCO, was submitted in September within the framework of PROMUSA in order to evaluate the risk associated with the dissemination of this virus alone, or in co-infection with BSV or CMV. A new PhD student is working at Gembloux to characterize the Colombian strain and to develop a reliable diagnostic kit.

**Banana streak virus (BSV)**

Discussions examined the clear evidence that BSV infection arises from viral sequences integrating into the *Musa* genome. Tissue culture is a factor that triggers episomal expression of integrated BSV sequences. Both ‘activatable’ (episomally-expressible) and ‘non-activatable’ (non-episomally-expressible) BSV sequences are integrated in the *Musa* genome.

One activatable BSV integrant (BSV-OL) is associated with the *Musa* B genome and not with the *Musa* A genome. Three other episomal BSV species (BSV-GF, BSV-IM and BSV-MYS) are integrated in the *Musa* genome. Like BSV-OL they appear to be associated with the *Musa* B genome. Initial evidence suggests that a series of other BSV integrants also occur in *Musa*. However, these have yet to be characterized.

Episomally-expressible (BSV-OL) and possibly episomally-expressible viral integrants (BSV-GF, BSV-IM) occur widely in plantains (AAB) and bananas (AAA) in Central and South America. The discussions concluded that these BSV species are not introduced into new areas in tetraploid AAAB hybrids produced by various *Musa* breeding programmes. BSV-OL and BSV-GF infection in AAA dessert bananas in Costa Rica, Ecuador and Venezuela result from pre-existing latent infection or from virus transmission from plantains.

Recommendations were made that:

- BSV indexing should be routinely done in commercial AAA banana tissue culture production

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### Current situation on *Musa* virus diagnostics and their availability

<table>
<thead>
<tr>
<th>Virus</th>
<th>Diagnostic(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBTV</td>
<td>ELISA</td>
<td>Commercial antiserum detects known strains</td>
</tr>
<tr>
<td></td>
<td>PCR</td>
<td>Sensitive but strain specific</td>
</tr>
<tr>
<td>BBrMV</td>
<td>Miniprep + ISEM</td>
<td>Polyclonal antiserum and recombinant antiserum available*</td>
</tr>
<tr>
<td></td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standardization with miniprep + ISEM</td>
<td></td>
</tr>
<tr>
<td>BanMMV</td>
<td>Miniprep + ISEM</td>
<td>Polyclonal antiserum available *</td>
</tr>
<tr>
<td></td>
<td>Standardised method</td>
<td></td>
</tr>
<tr>
<td>AbaMV</td>
<td>Miniprep + ISEM</td>
<td>Polyclonal antiserum available *</td>
</tr>
<tr>
<td></td>
<td>Standardized method</td>
<td></td>
</tr>
<tr>
<td>CMV</td>
<td>ELISA</td>
<td>Commercial antiserum available detects both serotypes</td>
</tr>
<tr>
<td></td>
<td>Standardized method</td>
<td></td>
</tr>
<tr>
<td>BSV (épisomal)</td>
<td>Miniprep + ISEM</td>
<td>Poly-polyclonal antiserum available* Detects episomal virus. Possible problems with strain variation. Possible problem with antiserum and primers on variation</td>
</tr>
<tr>
<td></td>
<td>IC-PCR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standardized method miniprep + ISEM</td>
<td></td>
</tr>
<tr>
<td>BSV (activatable intégrant)</td>
<td>PCR</td>
<td>Strain specific. Depends on strain sequence information.</td>
</tr>
<tr>
<td>Other viruses</td>
<td>Miniprep + EM</td>
<td>Detects presence of rod-shaped viruses and, coupled with antiserum* detects previously unrecognized viruses. More difficult with low concentration isometric viruses.</td>
</tr>
</tbody>
</table>

* Not available for commercial detection.
* Some antibodies available against BDBV.
• Research needs to be done immediately on the role of mealybugs in BSV transmission in the field. Episomal expression of BSV integrants in the Musa B genome appears to require the presence of the A genome. This model is supported from data from similar phenomena in tobacco and petunia. Immunocapture PCR (IC-PCR) is ten times more sensitive than ISEM in detecting BSV. More research is needed to resolve outstanding questions about the reliability of the technique.

Other viruses
A brief discussion was held on other rod-shaped viruses found in Musa germplasm. In particular potyvirus-like particles have been found in germplasm from Sri Lanka. Isometric virus particles have also been found in Musa spp. in Nigeria. The virus, tentatively named banana dieback virus (BDBV, genus ? Nepovirus) causes severe dieback symptoms and appears to spread slowly in the field. The production of diagnostics (polyclonal, monoclonal, primers) is in progress.

Priorities for virology research involving genetic improvement
• Development of reliable diagnosis of BSV, using appropriate diagnostics in an informed manner, by developing a better understanding of BSV diversity and through education on the significance of A and B genome
• Production of a PROMUSA pamphlet on current procedures for virus diagnosis
• Better understanding of B genome heterogeneity
• Better understanding of the contribution of the A genome in activating virus integrants in advanced breeding lines
• Mechanism to silence BSV integrants in the genome
• Research into the geographical diversity of BSV vis-à-vis movement of germplasm, particularly with respect to epidemiological information and risk assessment
• Development of resistance screening methods
• Securing supplies of diagnostics
• Research into the possibility and applicability of producing virus-‘free’ plantlets, particularly with respect to BanMMV and BSV.

Functioning of PROMUSA
The final part of the discussions focussed on the functioning of PROMUSA. PROMUSA has facilitated communication within the group. However there is a need to strengthen inter-working group linkages. A suggestion was made to set up a ‘convenors group’ to enable information, research results and needs to be disseminated to members of the appropriate groups. A request was also made for a ‘fire-walled’ Internet site to be set up to allow members of working groups to deposit information, such as incomplete sequence data, for the use of the working group alone. There is also a need to invite virologists from countries such as India and China to take part in the working group.

Participants of the Virology working group.