Nutritious bananas

Bacterial wilt in Uganda

Leaf area revisited

Focus on weevils

Jean Champion

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A look ahead

We all differ in the amount of change that we appreciate. However, the truth is that the agricultural research and development scene is continuously evolving and, as in the biological world, organizations that do not adapt to new conditions are destined to suffer the same fate as the dinosaurs. We open, then, this second ‘new-look’ edition of InfoMusa with the news that the International Plant Genetics Resource Institute (IPGRI), of which INIBAP is a programme, is in the process of developing a new strategy to carry it forward into the next decade. No doubt INIBAP will evolve along with it.

Over the next few months, we shall be contacting as many of our stakeholders as possible to obtain their input into the strategy development process. We hope that you will respond positively in helping us to identify and preserve the elements of our agenda that you value the most and that you will use this opportunity to seek changes in those elements that you do not appreciate. We also aim to identify new services that would be of value to you as we try to provide support to our diverse partners across the spectrum of Musa research and development activities.

One issue that will surely receive special attention and gain greater prominence through the strategy revision process is poverty alleviation. Looking at the work of INIBAP and its partners around the world during my first few months on the job, I have been struck by the similarity of the challenges faced by Musa research and development workers in different regions.

Although each works in a different social context — and sometimes in a markedly different economic climate — the underlying biological processes in the Musa cropping system remain the same. I believe that we can be much more effective in sharing our knowledge of crop ecology, as well as exchanging practical experiences of developing options, with Musa farmers, to manage these processes more effectively. A recent workshop in Costa Rica, focusing on interactions between pests, diseases and soil fertility around the Musa rhizosphere pointed in this direction and the international Musa congress, scheduled for July 2004 in Penang, Malaysia, will provide another opportunity for such exchanges.

In the year ahead, INIBAP and its partners will be organizing workshops in Africa, Latin America and probably Asia as well, to look at opportunities for developing the diverse options for marketing bananas and banana products which will help to realize the full potential of this crop to improve livelihoods. If we can extend the same model of building and integrating knowledge, and exchanging practical experiences that has proven so successful in Musa genetic improvement, to include more sustainable production systems and more flexible marketing opportunities, then we shall be truly on the way to developing a balanced programme to support the needs of Musa research and development in the years ahead.

Richard Markham
Director
Banana is one of the major traditional staple foods in the four states – Pohnpei, Kosrae, Chuuk and Yap – that make up the Federated States of Micronesia (FSM). However, since the 1970s, there has been a great decrease in the consumption of banana and other traditional locally grown foods, along with an increased consumption of imported foods, such as rice, wheat flour, sugar and fatty meat. There has also been a shift from bananas with a deep yellow and orange-colored flesh to introduced varieties with light-colored flesh.

At the same time, vitamin A deficiency (VAD) is an emerging problem among FSM children and women. The increase in VAD seems to be related to a decline in the consumption of local foods. However, it is not clear which foods protected people in the past. The commonly recognized sources of vitamin A, such as, milk, eggs, dark green leafy vegetables, ripe mango and ripe papaya, were not regularly eaten in FSM in the past. Fish liver, another vitamin A-rich food, is eaten by adults but is rarely given to young children.

A study of the nutrient content of bananas was initiated in FSM due to the emergence of a serious problem of VAD among children and women (Lloyd-Puryear et al. 1989, Centers for Disease Control and Prevention 2001, Auerbach 1994). There is a need to identify local vitamin A-rich foods that can be promoted to alleviate VAD. Not being considered as a rich source of vitamin A, local banana cultivars had never been analysed for their nutrient content even though some of them have a deep yellow or orange color associated with carotenoids. Provitamin A carotenoids are substances that are converted in the body to vitamin A and protect against VAD. β-carotene is the provitamin A carotenoid contributing the most to vitamin A status.

**Carotenoid-rich cultivars**

An ethnographic approach, using interviews with key informants, was adopted in order to identify cultivars most likely to be high in provitamin A carotenoids, based on their colour. The colour of the flesh of the fruit was determined visually. As most FSM banana cultivars are not marketed and some are rare, considerable time was needed to locate and collect samples. Moreover, most banana cultivars have different names in each state and people know mainly the names of bananas in their own language. There were only a few partial listings of banana cultivars by state and no listing for FSM providing documentation of the multiple names of cultivars between the states (Watson 1993, Merlin et al. 1992, Merlin and Juvik 1996, Merlin et al. 1996, Merlin et al. 1993, Sarfert 1919). In Pohnpei, there appears to be a number of cultivars with multiple names.

Composite samples (between 2 to 16, usually 3, ripe fruits/sample) were collected, frozen and transported (continuous cold-chain) to the laboratories. There they were analysed for carotenoids by high performance liquid chromatography. The samples were prepared raw or cooked (baked, boiled or steamed). Four laboratories carried out the analyses: the Cancer Research Center of Hawaii in Honolulu, Hawaii; Covance Laboratories in Madison, Wisconsin; University of the South Pacific in Suva, Fiji; and Roche Vitamins Ltd in Basel, Switzerland. The bananas

**Nutritional value**

L. Englberger

**Carotenoid-rich bananas in Micronesia**

L. Englberger
were analysed for β- and α-carotene, the common provitamin A carotenoids. 

β-carotene equivalents (sum of β-carotene content and half of α-carotene, which has half the vitamin A activity as β-carotene) were calculated in order to compare total provitamin A carotenoid content. The results of the duplicate analyses varied by less than 10% of each other (Fiji laboratory). The standard error of the mean for the Swiss analyses ranged from 8.5-9.4%.

Of the 17 FSM banana cultivars analysed, 12 contained enough provitamin A carotenoids to meet at least half of the estimated vitamin A requirements for a non-pregnant, non-lactating woman (Englberger et al. 2003b, Englberger et al. 2003a) (Table 1). The content of β-carotene ranged from 30 µg/100 g edible portion for the light-colored ‘Usr kufafa’ (AAB, Silk) to 6360 µg/100 g edible portion for the orange ‘Uht en yap’ (Fe’i). Carotenoid levels increased with the intensity of flesh coloration.

Five banana cultivars had β-carotene levels greater than 525 µg/100 g, more than 25 times the β-carotene level found in Cavendish bananas analysed in North America and Europe (Holden et al. 1999, Holland et al. 1991).

Carotenoid levels generally increase with cooking, as in cooked food the solvent better extracts the carotenes from the food matrix, and in this study carotenoid levels generally increased but not in all cases. Maturity also affects carotenoid content, i.e. green bananas contain very little.

Among the carotenoid-rich cultivars were Fe’i and other bananas that are somewhat rare and more difficult to grow. However, there were several non-Fe’i carotenoid-rich bananas that are commonly available and well liked. This greatly increases the potential of carotenoid-rich bananas in FSM and possibly elsewhere where they may grow.

Also two Micronesian banana cultivars, ‘Karat’ and ‘Taiwang’ (‘Pisang kelat’, AAB) were analysed in this study for nine minerals. Both cultivars contained high levels of potassium, similar to other bananas, and ‘Karat’ contained significant levels of calcium (Englberger et al. 2003a).

### Uses of Fe’i and other FSM bananas

The Fe’i bananas of the Australimusa Series have distinctive erect bunches and red sap (Daniells 1995, Sharrock 2000). Contrary to reports saying that they are only eaten raw, the Fe’i bananas ‘Karat’ and ‘Uht en yap’ are commonly eaten ripe and raw, in addition to being eaten ripe and cooked. The texture of ‘Karat’ is soft, and the taste is sweet and well liked. Informants indicate that a greater proportion of ‘Karat’ is eaten raw, whereas ‘Uht en yap’ is more often eaten cooked.

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**Table 1. Comparison of ripe Micronesian banana cultivars for their contribution to meeting daily vitamin A requirements:** 500 Retinol Equivalents (RE) for non-pregnant, non-lactating females 19-65 years; 400 RE for children 1-3 years (FAO/WHO, 2002).

<table>
<thead>
<tr>
<th>Local names</th>
<th>Genome and subgroup</th>
<th>Colour</th>
<th>Cooking method</th>
<th>N</th>
<th>Lab</th>
<th>β-carotene equivalent µg/100g</th>
<th>µg RE if 1000 g eaten/day</th>
<th>µg RE if 500 g eaten/day</th>
<th>µg RE if 250 g eaten/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uht en yap/Usr kolontol</td>
<td>Fe’i</td>
<td>orange</td>
<td>baked</td>
<td>3</td>
<td>I, R</td>
<td>4960</td>
<td>8267</td>
<td>4133</td>
<td>2067</td>
</tr>
<tr>
<td>Usr wac</td>
<td>AAB, plantain-like</td>
<td>orange</td>
<td>boiled</td>
<td>2</td>
<td>I, R</td>
<td>2598</td>
<td>4330</td>
<td>2165</td>
<td>1083</td>
</tr>
<tr>
<td>Ipali (same as Usr wac es sie?)</td>
<td>AAB, plantain-like</td>
<td>orange</td>
<td>boiled</td>
<td>2</td>
<td>I, R</td>
<td>1349</td>
<td>2248</td>
<td>1124</td>
<td>562</td>
</tr>
<tr>
<td>Usr kuria</td>
<td>not available</td>
<td>yellow</td>
<td>steamed</td>
<td>1</td>
<td>I</td>
<td>892</td>
<td>1487</td>
<td>743</td>
<td>372</td>
</tr>
<tr>
<td>Karat/Usr kulasr</td>
<td>Fe’i</td>
<td>yellow-orange</td>
<td>steam/boiled</td>
<td>3</td>
<td>I, R</td>
<td>867</td>
<td>1445</td>
<td>723</td>
<td>361</td>
</tr>
<tr>
<td>Usr wac es sie</td>
<td>AAB, plantain-like</td>
<td>yellow-orange</td>
<td>steamed</td>
<td>1</td>
<td>I</td>
<td>859</td>
<td>1431</td>
<td>716</td>
<td>358</td>
</tr>
<tr>
<td>Usr macaco</td>
<td>AA, Lakatan</td>
<td>yellow-orange</td>
<td>boiled</td>
<td>2</td>
<td>I, R</td>
<td>837</td>
<td>1395</td>
<td>698</td>
<td>349</td>
</tr>
<tr>
<td>Akatan/Usr lakatan</td>
<td>AAA, Green red</td>
<td>yellow</td>
<td>steamed</td>
<td>1</td>
<td>I</td>
<td>773</td>
<td>1288</td>
<td>644</td>
<td>322</td>
</tr>
<tr>
<td>Mangat</td>
<td>not available</td>
<td>yellow</td>
<td>raw</td>
<td>1</td>
<td>C</td>
<td>575</td>
<td>958</td>
<td>479</td>
<td>240</td>
</tr>
<tr>
<td>Usr taiwang</td>
<td>AAB, Pisang kelat</td>
<td>yellow</td>
<td>boiled</td>
<td>1</td>
<td>R</td>
<td>490</td>
<td>816</td>
<td>408</td>
<td>204</td>
</tr>
<tr>
<td>Uht en kerinis</td>
<td>AAB, Pisang raja</td>
<td>yellow</td>
<td>raw</td>
<td>1</td>
<td>I</td>
<td>415</td>
<td>692</td>
<td>346</td>
<td>173</td>
</tr>
<tr>
<td>Usr in yeir</td>
<td>AAB, Popoulu</td>
<td>yellow</td>
<td>boiled</td>
<td>2</td>
<td>I, R</td>
<td>390</td>
<td>650</td>
<td>325</td>
<td>163</td>
</tr>
<tr>
<td>Marech</td>
<td>not available</td>
<td>yellow</td>
<td>raw</td>
<td>1</td>
<td>I</td>
<td>232</td>
<td>387</td>
<td>193</td>
<td>97</td>
</tr>
<tr>
<td>Usr apto poel/ Inasio</td>
<td>ABB, Bluggoe</td>
<td>creamy</td>
<td>boiled</td>
<td>1</td>
<td>R</td>
<td>155</td>
<td>258</td>
<td>129</td>
<td>65</td>
</tr>
<tr>
<td>Uht en ruk/Usr apart fusus</td>
<td>ABB, Saba</td>
<td>creamy</td>
<td>boiled</td>
<td>3</td>
<td>R</td>
<td>148</td>
<td>247</td>
<td>123</td>
<td>62</td>
</tr>
<tr>
<td>Usr Fiji/Uht en phisi (Fiji)</td>
<td>AAB, Mysore</td>
<td>creamy-white</td>
<td>raw</td>
<td>1</td>
<td>I</td>
<td>77</td>
<td>128</td>
<td>64</td>
<td>32</td>
</tr>
<tr>
<td>Usr kufafa/Uht en mehitha</td>
<td>AAB, Silk</td>
<td>white</td>
<td>raw</td>
<td>1</td>
<td>R</td>
<td>40</td>
<td>67</td>
<td>33</td>
<td>17</td>
</tr>
</tbody>
</table>

* Number of duplicate analyses of composite samples from which β-carotene equivalents were calculated.

I - IAS/USP, Suva, Fiji; R - Roche Vitamins, Basel, Switzerland; C - Covance Laboratories, Madison, Wisconsin.
‘Karat’ is the traditional weaning food in Pohnpei and is believed to have special health benefits. It is quite distinctive for its very fat fingers and deep yellow-orange flesh. Although this banana was first identified simply as ‘Karat’, further work in Pohnpei shows that there are at least two types: ‘Karat pwehu’, which has a fat oblong finger (often 200 grams in weight), and ‘Karat pako’, which has an even larger fat oblong finger (often 400 grams in weight). Informants explained that ‘Karat’ is prepared in a special way for young children. Because of its thick skin, the unpeeled finger can be pressed and the flesh softened without the banana skin rupturing. The top of the finger is removed and children enjoy sucking out the contents, somewhat like eating an ice cream cone. It also has an important cultural significance and is one of the few banana cultivars in Pohnpei that can be used in ceremonial presentations.

‘Uht en yap’ is much rarer than ‘Karat’ and has a distinctive cone-like shaped bunch, small fingers and deep orange flesh. ‘Karat’ became rare due to neglect, similar to all other local foods, and also because newly introduced bananas were easier to grow. It was first analysed in 1998 and found to contain high levels of carotenoids. A one-year promotional campaign, involving the media, primary schools and community groups, and a distribution of planting material, was carried out in Pohnpei in 1999 to raise awareness on its nutrient content (Englberger 1999). This program was successful in that ‘Karat’ had not previously been sold at local markets but following the campaign, it started appearing regularly (although still in limited amounts) (Englberger 2002). Market surveys before and after the campaign and key informant interviews indicated that it was the campaign that was responsible for the increase in production. This showed that a promotional campaign of a banana cultivar can have an important impact on behaviour if beliefs and practices are taken into account. Furthermore, due to the identification of vitamin A-rich banana cultivars, a program was set in place in Kosrae to produce tissue-culture planting material (Josekutty et al. 2002).

Although bananas are well liked, some FSM people consider banana as a poor man’s food since it is more available than other traditional staple foods and is also cheaper in the market. In Pohnpei a common cooking banana ‘Uht en ruk’ (Saba, ABB) is sold usually at US$0.55 a kilogramme, whereas breadfruit and yam are sold at US$1.10 and US$2.75 per kilogramme respectively. In most Pohnpei shops, ‘Karat’ is usually sold at US$1.10 per kilogramme, indicating its value and demand. One carotenoid-rich cultivar, ‘Taiwang’, has very low status due to its common availability; it was not marketed in the past and is often grown simply for feeding the pigs. On the other hand, that cultivar is liked for its sweet taste and is valued in Kosrae for making the traditional pounded fafa dish. After a short promotion, it is now marketed in Kosrae and Pohnpei. In addition to bananas used for consumption, there has been a cultivar grown traditionally for its fiber and for making cloth; in Kosrae this is ‘Usr kusus’ (Musa textilis) but it is now rare. Some bananas are highly valued for medicinal qualities. Banana leaves have important uses in food preparation and covering the traditional earth oven.

Conclusion

This study has shown that some cultivars contain high levels of provitamin A and total carotenoids, in addition to important levels of vitamin C, fiber and potassium (Dignan et al. 1994). Epidemiological research suggests that carotenoid-rich foods protect against certain chronic disease including diabetes, heart disease and cancer (Ford et al. 1999, Bertram 2002). Thus, these
Micronesian carotenoid-rich bananas may also protect against those diseases, which are now serious problems in FSM. Further research in FSM and elsewhere is needed to identify further carotenoid-rich cultivars that may effect health improvement and that may be acceptable for increased production and consumption.

Acknowledgements

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References


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In August 2001, the Mukono district agricultural extension staff reported a previously unknown banana disease with wilt-like symptoms spreading rapidly in the village of Bulyanti, in Uganda. In response, a team of plant pathologists from the National Agricultural Research Organization (NARO) and Mukono District extension workers visited the affected area. Among the farmers visited was Mr Musiitwa, who first reported the disease and whose plantation was the most affected. Several other neighbouring plantations were also visited and disease assessments done. Samples of diseased tissues were collected for isolation and identification of the causal pathogen. Samples were sent to CABI Bioscience in the United Kingdom for further isolation and identification of the causal organism. Farmers and extension workers were asked to report new sightings of the disease. This report summarizes the disease diagnostic activities undertaken and the measures implemented to contain the disease.

The disease

Results from CABI suggested that a bacterium, Xanthomonas campestris pv. musacearum, was the causal agent. Pathogenicity tests (Koch’s postulate) confirmed the disease. This bacterium is known to cause wilt in Ensete and in bananas in Ethiopia (Yirgou and Bradbury 1968, 1974).

The disease was observed on both East African highland bananas and exotic (dessert/beer) bananas, but given the prevalence of highland bananas, these were the most affected. In one particular field, the incidence was estimated at 70%, but some of the affected plants had been slashed and uprooted in an attempt to control the disease and it was difficult to identify the symptoms on the uprooted stumps. Despite this, it was evident that the incidence in some of the fields was considerably high.

According to a number of farmers interviewed, the disease was first observed around October 2000 on Mr Musiitwa’s plantation. Thereafter, it spread to several plantations in the surrounding areas. The team and farmers failed to establish how the disease entered the area. It first appeared in a plantation that was over seven years old, suggesting that it had not been transmitted with the planting material. The farmers with the problem indicated that they had gotten their planting materials from local sources. It was not possible to establish the source of the disease from discussions with farmers.

External symptoms

The disease was mostly observed on plants past the maiden sucker stage (although some younger suckers also had symptoms) and recently flowered plants. The major characteristics of the disease are yellowing and complete wilting of the plant starting with the most peripheral leaves, as with fusarium wilt of bananas. However, unlike fusarium wilt, which does not affect East African cultivars, this bacterium affected all banana types. The fruits exhibited discoloration of the pulp when they were sectioned (Figure 1).

After wilting, the leaves tend to droop and the plant eventually stops growing and dies. Secretion of bacterial ooze could also be seen on leaves. Such secretions are absent in the case of fusarium wilt and can be used to distinguish the two diseases on cultivars that are also affected by fusarium wilt (e.g. ‘Pisang awak’ and ‘Gros Michel’).

The most commonly observed symptoms are wilting and premature ripening of the bunch, sometimes before it is one month old. In flowered plants, leaves may show wilting symptoms while the bunch is still green, but these bunches eventually ripen and may also wilt.

In heavily affected plants the male bud appears wilted and sometimes discolored (Figure 2). The male bud stalk has yellow discoloration progressing from the base of the male bud towards the bunch. A cream-coloured ooze, typical of many bacterial infections, can be seen in the area closest to the male bud.

Internal symptoms

A pale yellow discoloration was observed in the cross section of the corm of most affected plants. When the pseudostems of affected flowered plants were sectioned,
discoloration was much more apparent in the central stalk that carries the bunch than in the outer leaf sheaths (Figure 3a). A lot of liquid was observed to ooze from the sectioned pseudostems of affected plants, and on leaving the sectioned tissues overnight, the ooze changed into a slimy liquid (Figure 3b).

When fingers from infected bunch were sectioned, they were stained reddish brown. In bananas, this symptom is only caused by bacterial wilt diseases and as such distinguishes this disease from all other banana diseases previously observed in Uganda. The pulp was soft, as when it is ripe, even though the bunch still needed about one and a half months to reach maturity.

Distribution
A survey done in January 2002 revealed that in the Mukono district, the disease was still restricted to a radius of 5 km from the farm where the disease was first identified. Extension workers in the neighbouring areas were asked to be on the lookout for the disease in other areas. By June 2003, the disease had been reported in more than 15 sub-counties distributed across the districts of Kayunga, Lira, Apac and Kaberamaido – all to the north of Mukono (northern and northeastern Uganda). It is speculated that the disease could have gotten into Mukono from northern Ugandan districts.

According to Yirgou and Bradbury (1974) long distance transmission of the disease is aided through:

a) Farm tools such as machetes, pangas and pruning knives. Contaminated tools transmit the bacteria through injuries on roots and aerial parts when farming.

b) Movement of infected plant materials (suckers, bunches, leaves).

c) Contamination of body parts (hands and feet).

d) Insects as they look for nectar in flowers.

e) Animals as they browse from infected to clean plants.

f) Water when it moves around infected soil.

Figure 1. Sectioned fingers of affected bunches.
Figure 2. Cross section of an affected (left) and unaffected (right) male bud.
Figure 3. Internal appearance of a pseudostem: a) pale yellow discoloration, immediately after sectioning, b) characteristic bacterial ooze, three days later.
g) Rain splash and wind. Rain is believed to aggravate the spread of the disease within a plantation during the rainy season.

Recommendations

It was recommended that general measures be implemented to prevent the spread of this bacterial wilt. They include:

- **Destroying and disposing of infected plants**
  The affected plants should be detected early enough and destroyed. Destruction should be complete so as not to allow re-growth.

- **Disinfecting tools used in managing the plantation**
  Once the disease is detected in a plantation, tools (pangas, pruning knives/leaf removers etc.) should be disinfected before using them on other plants.

- **Avoiding planting materials from infected fields**
  Systemic and soil-borne diseases, such as this banana wilt, are mostly transmitted through diseased planting materials. It is recommended that farmers avoid getting suckers from plantations (areas) where the disease has been sighted. In fact, sucker exchange within the area should be strongly discouraged.

- **Removing male buds**
  It is reported that insects also spread the bacteria as they visit banana flowers. It is recommended to remove the male bud by breaking the supporting peduncle as soon as the last hand of the bunch emerges.

- **Keeping browsing animals out of infected fields**
  The animals move the disease from plant to plant as they browse. Farmers are advised to keep them out.

- **Replacing bananas with another crop**
  Heavily infected plantations should be replaced with another crop for at least two years.

**Quarantine measures**

It has been noted that the danger of this disease spreading across the country is very high if measures to contain it are not immediately enforced. Local quarantine measures have been recommended to supplement the disease management measures suggested above. Farmers’ awareness of the disease and their full participation in devising/implementing control measures has been adopted to contain the disease.

References


Results of a survey on nematodes of *Musa* in household gardens in South Africa and Swaziland

*M. Daneel, N. Dillen, J. Husselman, K. De Jager and D. De Waele*

In South Africa, about 280 000 tons of Cavendish bananas are commercially produced annually on some 16 000 hectares of land. On the cultivation of banana in household gardens in rural areas, however, almost no information exists. Therefore, a preliminary survey was conducted in the main banana growing rural areas of South Africa and neighbouring Swaziland to collect baseline information on the *Musa* varieties grown and the major diseases and pests associated with these bananas. Only the results on nematodes are reported here.

**Materials and methods**

The survey was conducted from August until October 2000. In South Africa, six areas were visited: Venda in the northern part of the Limpopo province; Bushbuck Ridge in the southern part of the Limpopo province; Komatiport, Nelspruit and Barberton in Mpumalanga province, northern Kwazulu-Natal; and southern Kwazulu-Natal and the southern part of the Eastern Cape (former Transkei) bordering southern Kwazulu-Natal. In Swaziland, samples were taken in the Lowveld area, which comprises the eastern and southern parts of the country (Figure 1).
The banana varieties grown in household gardens were identified and the other crops grown were also noted. The banana plants identified were examined for symptoms of diseases. To study the presence of plant parasitic nematodes, one soil and root sample from the different varieties per site (mostly two varieties) was collected according to the methodology described by Speijer and De Waele (1997). The roots were evaluated for root necrosis index and root-knot index. In the laboratory, the nematodes were extracted from the soil and root samples using a sugar flotation technique (Jenkins 1964) and counted.

Results and discussion
The *Musa* varieties most commonly grown were ‘Pisang awak’ (ABB) and Cavendish bananas (AAA) (Table 1). ‘Pisang awak’ was always present in greater numbers than Cavendish bananas, except at the Eastern Cape and southern Kwazulu-Natal. In the tropics, ‘Pisang awak’ is a cooking and beer banana but in the subtropics, such as in South Africa, its fruit is reasonably sweet and can be eaten without cooking. When compared to Cavendish bananas, ‘Pisang awak’ has a more acid taste and can only be eaten when it is fully ripe. Plantains (AAB) were only found in very limited numbers.

In 93% of the household gardens visited, bananas were cultivated in a mixed cropping system, compared to 7% in a monoculture. In descending order of importance, mango, papaya, avocado, citrus, guava, peach and mulberry were the other fruit trees present. Other crops observed included sugarcane, cassava, vegetables and some grain crops. Since the survey was carried out in winter, mostly vegetables were observed: tomatoes, spinach, pumpkin, sweet potato and cabbage. In traditional cropping systems, vegetables are grown during winter and grains during summer. Avocado trees were most abundant in the Bushbuck Ridge area. Peaches, avocado and guavas were rarely found in northern Kwazulu-Natal. In general, farmers cultivated either mango or citrus except in one site where both trees were found. In the Eastern Cape and Swaziland few vegetables were found, in contrast to the other areas. Fruit trees are not very susceptible to nematodes but most of the vegetables planted are highly susceptible. Nematodes samples were not taken from the vegetables and other fruit crops but other surveys in these areas on vegetables have shown high infestation levels in the vegetables (Fourie et al. 2002).

Rural communities often depend for food security on the harvest of crops produced in household gardens. These crops are mostly grown for home consumption and only the excess is sold to generate income. This is also the case for bananas.

The main constraint for banana production in household gardens is shortage of water. In one-third of all sites and about 80% of the sites visited in Eastern Cape and southern Kwazulu-Natal, only rainwater was available. Table 2 shows the annual rainfall as well as the number of rainy days in the areas surveyed. In contrast to the tropics, rainfall in South Africa is limited to 3 to 4 months. Irrigation is practically nonexistent in household gardens and often water has to be carried over long distances. Although the high temperatures coincide with the wetter months (October until February), the drought...
period is too long for an optimal growth of bananas. Areas with the highest rainfall are Eastern Cape and southern Kwazulu-Natal, followed by Bushbuck Ridge and Venda. According to Robinson (1993), optimal banana growth is obtained when the minimum air temperature exceeds 18°C. In Venda and northern Kwazulu-Natal, 6 months have the required minimum air temperature, followed by Komatipoort with 5 months and Eastern Cape and southern Kwazulu-Natal with 4 months (Table 2). Nematodes were recovered from practically all soil and root samples (Table 3).

Root-knot (Meloidogyne spp.) and spiral (Helicotylenchus spp.) nematodes were found in more than 90% of the root samples examined while Radopholus similis was recovered from about 9% and Pratylenchus coffeae from only 3% of the root samples. However, in northern Kwazulu-Natal, R. similis was found in 40% (12 out of 29) of the root samples while in Swaziland and the Eastern Cape and southern Kwazulu-Natal, P. coffeae was found in 14.3 (1 out of 7) and 7.7% (3 out of 38), respectively, of the root samples.

Table 4 lists the average population density, and minimum and maximum values, for the four most important plant parasitic nematode species identified in the roots of the sampled Musa varieties. Population densities of Meloidogyne spp. and Helicotylenchus multicinctus tended to be very high while these of R. similis and P. coffeae were in general very low. No differences in nematode population densities between ‘Pisang awak’ and Cavendish bananas were observed, suggesting that both varieties are highly susceptible to these nematode species. Where ‘Pisang awak’ and Cavendish bananas were grown next to each other, roots of ‘Pisang awak’ showed a more healthy root system compared to Cavendish bananas. However, this was apparently not due to a difference in nematode numbers but more likely due to the thicker root system of ‘Pisang awak’. In the plantains, nematode densities were high except in northern Kwazulu-Natal where numbers of both Meloidogyne spp. and Helicotylenchus multicinctus in the roots were low. In none of the sites was the root necrosis index higher than 10, a result which can be explained by the low frequency of occurrence and the low abundance of the root-lesion nematodes, R. similis and P. coffeae.

Based on climatological conditions, areas such as Venda and northern Kwazulu-Natal are very well suited for banana production in household gardens in South Africa, especially when farmers have access to irrigation schemes (as is the case in northern Kwazulu-Natal). Because maize is favored as the staple food and people do not know how to process cooking bananas, there is little demand for this type of banana in South Africa. However, in view of chronic nutrient deficiencies in the rural areas of South Africa, promoting the cultivation and consumption of cooking bananas might be a good solution to alleviate this problem and increase food security. However, more intensive cultivation could result in increased

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**Table 2. Weather data in the areas surveyed in South Africa**

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of years of data</th>
<th>Number of rainy days in a year</th>
<th>Number of months with minimum air temperature above 18°C</th>
<th>Annual rainfall (mm)</th>
<th>Tn</th>
<th>M</th>
<th>Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venda</td>
<td>19</td>
<td>958.6</td>
<td>64.9</td>
<td>10.2</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bushbuck Ridge</td>
<td>25</td>
<td>1020</td>
<td>77.1</td>
<td>10.2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Komatipoort</td>
<td>25</td>
<td>659.9</td>
<td>48.3</td>
<td>9.0</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelspruit and Barberton</td>
<td>70</td>
<td>775.6</td>
<td>62.3</td>
<td>6.5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Kwazulu-Natal</td>
<td>22</td>
<td>666.8</td>
<td>82.7</td>
<td>7.6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Cape and southern Kwazulu-Natal</td>
<td>21</td>
<td>1240</td>
<td>90.6</td>
<td>12.7</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tn = daily minimum air temperature; M = number of months with minimum air temperature above 18°C; Tx = daily maximum air temperature.

**Table 3. Frequency of occurrence of plant parasitic nematodes associated with banana grown in household gardens in South Africa and Swaziland**

<table>
<thead>
<tr>
<th>Nematodes</th>
<th>% of soil samples with nematodes</th>
<th>n</th>
<th>% of root samples with nematodes</th>
<th>n</th>
<th>Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meloidogyne spp.</td>
<td>96.3</td>
<td>152</td>
<td>93.8</td>
<td>147</td>
<td>All areas</td>
</tr>
<tr>
<td>Helicotylenchus spp.</td>
<td>96.3</td>
<td>152</td>
<td>93.2</td>
<td>146</td>
<td>All areas</td>
</tr>
<tr>
<td>Radopholus similis</td>
<td>3.7</td>
<td>0</td>
<td>8.9</td>
<td>1</td>
<td>BBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
<td></td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>12</td>
<td></td>
<td>N KZN</td>
</tr>
<tr>
<td>Pratylenchus coffeae</td>
<td>7.6</td>
<td>5</td>
<td>3.2</td>
<td>1</td>
<td>BBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>3</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
<tr>
<td>Rotylenchus spp.</td>
<td>4.4</td>
<td>4</td>
<td>1.2</td>
<td>0</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td></td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td>BBR</td>
</tr>
<tr>
<td>Paratrichodorus spp.</td>
<td>7.0</td>
<td>11</td>
<td>-</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
<tr>
<td>Cricoceroides spp.</td>
<td>5.7</td>
<td>4</td>
<td>-</td>
<td></td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>-</td>
<td></td>
<td>N KZN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>-</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
<tr>
<td>Tylenchus spp.</td>
<td>1.9</td>
<td>3</td>
<td>-</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
<tr>
<td>Aphelenchoides spp.</td>
<td>8.9</td>
<td>4</td>
<td>-</td>
<td></td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>-</td>
<td></td>
<td>BBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>-</td>
<td></td>
<td>N KZN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>-</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
<tr>
<td>Paratylenchus spp.</td>
<td>0.6</td>
<td>1</td>
<td>-</td>
<td></td>
<td>EC &amp; S KZN</td>
</tr>
</tbody>
</table>

n: number of samples in which nematode species were found; V=Venda; BBR=Bushbuck Ridge; K=Komatipoort; S=Swaziland; N KZN=Barberton in Mpumalanga province, northern Kwazulu-Natal; EC & S KZN=southern Kwazulu-Natal and the southern part of the Eastern Cape (former Transkei) bordering southern Kwazulu-Natal.
damage by root-knot nematodes, which are already omnipresent in high population densities on banana in South Africa. The *Meloidogyne* problem could be aggravated by the custom of growing banana together with vegetables, which are excellent host plants of these nematodes.

### References


### Table 4. Average population density (min-max), root necrosis index (RNI) and root-knot index (RKI) of the most common nematodes found on bananas grown in household gardens in South Africa and Swaziland

<table>
<thead>
<tr>
<th>Area</th>
<th>Cultivar</th>
<th>H. m. Nematodes per 100 g roots</th>
<th>M. spp. (n=24)</th>
<th>R. s. (n=6)</th>
<th>P. c. (n=1)</th>
<th>RKI</th>
<th>RNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venda</td>
<td>P. awak</td>
<td>5517 (167-21-670)</td>
<td>5570</td>
<td>7 (0-170)</td>
<td>0 (0-10)</td>
<td>8.1</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>4139 (170-13 170)</td>
<td>9500</td>
<td>10 (0-170)</td>
<td>0 (0-10)</td>
<td>12.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Bushbuck Ridge</td>
<td>P. awak</td>
<td>17 923 (3500-33 330)</td>
<td>8893</td>
<td>7 (0-167)</td>
<td>0 (0-10)</td>
<td>2.9</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>21 677 (0-105 390)</td>
<td>6830</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>0.9</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Plantains</td>
<td>18 167</td>
<td>7500</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Komatipoort</td>
<td>P. awak</td>
<td>4403 (670-9330)</td>
<td>5523</td>
<td>0 (0-167)</td>
<td>233 (0-830)</td>
<td>2.7</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>1600 (170-3670)</td>
<td>13 667</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>3.4</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Plantains</td>
<td>3167 (170-8000)</td>
<td>25 167</td>
<td>57 (0-167)</td>
<td>0 (0-10)</td>
<td>8.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Nelspruit and Barberton</td>
<td>P. awak</td>
<td>483 (167-800)</td>
<td>7383</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>4.5</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>4500 (0-10 833)</td>
<td>375</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>1.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Northern Kwazulu-Natal</td>
<td>P. awak</td>
<td>9460 (0-55 790)</td>
<td>10 920</td>
<td>0 (0-167)</td>
<td>233 (0-830)</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>5943 (0-47 000)</td>
<td>5490</td>
<td>0 (0-167)</td>
<td>0 (0-10)</td>
<td>1.1</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Plantains</td>
<td>667 (0-2500)</td>
<td>917</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Eastern and southern Kwazulu-Natal</td>
<td>P. awak</td>
<td>9787 (500-46 500)</td>
<td>4973</td>
<td>0 (0-170)</td>
<td>187 (0-300)</td>
<td>4.6</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>6346 (500-44 286)</td>
<td>2962</td>
<td>0 (0-170)</td>
<td>43 (0-670)</td>
<td>2.7</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Plantains</td>
<td>5223 (667-14 330)</td>
<td>23 723</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>6.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Swaziland</td>
<td>P. awak</td>
<td>5267 (0-17 670)</td>
<td>1767</td>
<td>0 (0-170)</td>
<td>133 (0-670)</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Cavendish</td>
<td>108 (0-217)</td>
<td>1250</td>
<td>0 (0-170)</td>
<td>0 (0-10)</td>
<td>2.5</td>
<td>10.4</td>
</tr>
</tbody>
</table>

P. awak=Pisang awak; H. m.=Helicotylenchus multicinctus; M. spp.=Meloidogyne spp.; R. s.=Radopholus similis; P. c.=Pratylenchus coffeae

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N. Dillen and D. De Waele work at the Laboratory of Tropical Crop Improvement, Katholieke Universiteit Leuven, Kasteelpark Arenberg 13, 3001 Leuven, Belgium.
Influence of weeding regime on the performance of ‘Basrai’ (AAA)

C.D. Badgujar, S.M. Dusane and S.S. Deshmukh

Among the cultural practices affecting banana cultivation, inadequate weeding is one of the most important factors limiting growth and yield. Frequent weeding is carried out by farmers to control weeds in this crop. The vegetative phase (1 to 6 months after planting) is the most critical period. Control of weeds during this period enhances fertilizer use efficiency and yield (Chadha 1999). Hemeng et al. (1994) reported a significantly higher number of leaves, maximum pseudostem girth and bunch weight following weeding at 4-week intervals. However, the scarcity and high cost of labour, due to competition with industry, limits the amount of weeding that is feasible. The present study was undertaken to evaluate the effect of not weeding at certain times to minimize the cost of weeding.

Materials and methods
The experiment was carried out between 1995 and 1998 at the Banana Research Station, Mahatma Phule Agriculture University, Jalgaon, as part of the All India Co-ordinated Research Project on tropical fruits. The banana cultivar ‘Basrai’ (AAA) was planted every year in June in 6 m × 6 m plots. In total, there were 32 plots (8 treatments replicated four times) containing 25 plants each. The spacing between plants was 1.5 m × 1.5 m. The experiment was laid out in a randomized block design.

T1: No weeding (control)
T2: Mostly weed-free (plot kept essentially weed-free throughout the crop cycle by hoeing and hand weeding)
T3: Hand weeding
T4: No weeding until 3rd month and then weed-free
T5: No weeding until 6th month and then weed-free
T6: Weeding until 3rd month, no weeding between 3rd to 6th month and then weed-free
T7: Weeding until 6th month, no weeding between 6th to 9th month and then weed-free
T8: Weeding until 9th month, no weeding between 9th to 12th month and then weed-free

The crop was uniformly fertilized with 200:40:200 g N:P:K per plant. Growth and yield parameters were recorded. The data from three years were pooled for statistical analysis.

The authors work at the Banana Research Station, Mahatma Phule Agriculture University, Jalgaon-425 001, India.

Results and discussion
All parameters showed significant impacts of weeding treatments on the agronomic parameters evaluated. The greatest pseudostem height and girth, and total number of leaves, the lowest number of days to flowering and to harvest, highest number of hands per bunch, finger length, finger girth and bunch weight were observed in the treatment (T9) that was most intensively weeded (Table 1). It was followed by treatments T3 (hand weeding) and T8 (weeding until 9th month, no weeding between the 9th to 12th months and then weed-free). Keeping the crop generally free of weeds (T2) resulted in a 47% increase in yield over the plants in the control group and in a cost/benefit ratio of 0.05. The second best treatment (hand weeding) showed a 34% increase in yield and a cost/benefit ratio of 0.08 (Table 2).

Similar results have been reported by Patel et al. (1999) with respect to the influence of different weeding frequencies on growth and yield of the cultivar ‘Basrai’. Durgadevi and Sathiamoorthy (1996), reporting on the influence of weed infestation on banana growth, found a 18% increase in bunch weight when the crop was weeded until the 9th month, left without weeding until the 12th month and then kept weed-free. They reported a yield loss of 54.7% when the crop was not weeded.

Despite the high cost of labour, it is worth keeping the crop free of weeds throughout the growth cycle.

References
Comparative efficiency of weed control methods on ‘Basrai’ (AAA)

C.D. Badgjur, S.M. Dusane and S.S. Deshmukh

Many factors are responsible for low yields, of which poor weed management is one of the most important. The most common way to address this constraint is by frequent hand weeding, but it often gets postponed until significant damage has been done to the crop. The cost, non-availability of labour during peak season and the tediousness of the work are some of the disadvantages of hand weeding. However, sowing of a fast growing crop such as cowpea in the inter-row space and its incorporation into the soil at flowering initiation, followed by a second crop of cowpea, helps to keep weeds in check.

The advantage of chemical weed control lies in a superior weed control at the most critical period of crop growth, thereby reducing fertilizer loss and resulting in increased yield at minimal cost of inputs. The effectiveness of applying Glyphosate and growing two crops of cowpea and incorporating them into the soil has been reported (Durgadevi and Sathiamoorthy 1996, Anon. 2000). Panta and Revista (1992) also observed the beneficial effect of Glyphosate on weed control, and Durgadevi and Sathiamoorthy (1996) of Gramoxone at 1.8 kg/ha. This study was undertaken to compare the efficiency of these weed control methods.

Materials and methods

Seven treatments, with 4 replications per treatment, were tested at the Banana Research Station, Mahatma Phule Krishi

Table 1. Effect of various weeding regimes on the agronomic performance of ‘Basrai’ (pooled mean of three years 1995-1998).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pseudostem height (cm)</th>
<th>Pseudostem girth (cm)</th>
<th>Number of leaves per plant</th>
<th>Days to flowering</th>
<th>Days to harvesting</th>
<th>Number of hands per bunch</th>
<th>Number of length (cm)</th>
<th>Finger girth (cm)</th>
<th>Bunch weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>147.6d</td>
<td>59.0c</td>
<td>30.3b</td>
<td>320c</td>
<td>428c</td>
<td>6.7c</td>
<td>18.5c</td>
<td>9.9</td>
<td>11.6e</td>
</tr>
<tr>
<td>T2</td>
<td>164.9a</td>
<td>69.2a</td>
<td>32.6a</td>
<td>265a</td>
<td>302a</td>
<td>9.2a</td>
<td>21.9a</td>
<td>11.2a</td>
<td>17.3a</td>
</tr>
<tr>
<td>T3</td>
<td>159.5b</td>
<td>64.7a</td>
<td>31.3a</td>
<td>289b</td>
<td>386a</td>
<td>8.6a</td>
<td>21.3a</td>
<td>10.9b</td>
<td>16.1b</td>
</tr>
<tr>
<td>T4</td>
<td>154.6c</td>
<td>62.4b</td>
<td>30.7b</td>
<td>307b</td>
<td>411b</td>
<td>7.5b</td>
<td>19.5b</td>
<td>10.3e</td>
<td>13.3d</td>
</tr>
<tr>
<td>T5</td>
<td>151.2c</td>
<td>57.3c</td>
<td>30.3b</td>
<td>321c</td>
<td>420b</td>
<td>7.2c</td>
<td>18.8c</td>
<td>9.7g</td>
<td>11.9e</td>
</tr>
<tr>
<td>T6</td>
<td>153.0c</td>
<td>62.0b</td>
<td>30.3b</td>
<td>293b</td>
<td>395b</td>
<td>8.1b</td>
<td>20.2b</td>
<td>10.6d</td>
<td>14.3c</td>
</tr>
<tr>
<td>T7</td>
<td>154.7c</td>
<td>64.0a</td>
<td>30.7b</td>
<td>264a</td>
<td>383a</td>
<td>8.0b</td>
<td>20.5b</td>
<td>10.8c</td>
<td>14.9c</td>
</tr>
<tr>
<td>T8</td>
<td>157.6b</td>
<td>64.9a</td>
<td>31.2a</td>
<td>287a</td>
<td>384a</td>
<td>8.7a</td>
<td>21.4a</td>
<td>10.9b</td>
<td>15.8b</td>
</tr>
<tr>
<td>SE</td>
<td>1.2</td>
<td>1.8</td>
<td>0.5</td>
<td>7.7</td>
<td>8.6</td>
<td>0.3</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>CD</td>
<td>3.3</td>
<td>5.6</td>
<td>1.5</td>
<td>23</td>
<td>26</td>
<td>0.7</td>
<td>1.2</td>
<td>0.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

T1: No weeding
T2: Mostly weed-free (plot kept essentially weed-free throughout the crop cycle by hoeing and hand weeding)
T3: No weeding until 3rd month and then weed-free
T4: Weeding until 3rd month, no weeding between 3rd to 6th month and then weed-free
T5: Weeding until 6th month, no weeding between 6th to 9th month and then weed-free
T6: Weeding until 9th month, no weeding between 9th to 12th month and then weed-free

Table 2. Effect of weeding on the yield and economic performance of ‘Basrai’ bananas

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (MT/ha)</th>
<th>Percent change over no weeding treatment (%)</th>
<th>Additional yield per ha over no weeding treatment (MT)</th>
<th>Additional income over no weeding treatment (Rs)</th>
<th>Additional treatment (Rs/ha)</th>
<th>Cost/benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>52.3</td>
<td>24.5</td>
<td>613.350</td>
<td>2857</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>76.8</td>
<td>46.9</td>
<td>24.5</td>
<td>613.350</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>71.7</td>
<td>37.1</td>
<td>19.4</td>
<td>48.475</td>
<td>3700</td>
<td>0.08</td>
</tr>
<tr>
<td>T4</td>
<td>59.1</td>
<td>12.9</td>
<td>6.8</td>
<td>16.925</td>
<td>2800</td>
<td>0.16</td>
</tr>
<tr>
<td>T5</td>
<td>52.9</td>
<td>1.3</td>
<td>0.7</td>
<td>1.700</td>
<td>1400</td>
<td>0.83</td>
</tr>
<tr>
<td>T6</td>
<td>63.8</td>
<td>11.5</td>
<td>11.5</td>
<td>28.700</td>
<td>4300</td>
<td>0.12</td>
</tr>
<tr>
<td>T7</td>
<td>66.2</td>
<td>26.5</td>
<td>13.9</td>
<td>34.700</td>
<td>4300</td>
<td>0.12</td>
</tr>
<tr>
<td>T8</td>
<td>70.1</td>
<td>34.1</td>
<td>17.8</td>
<td>44.575</td>
<td>3700</td>
<td>0.08</td>
</tr>
</tbody>
</table>

See table 1 for information on treatments

Daily labour cost: Rs 30; cost of hoeing: Rs 500/ha; Price of bananas: Rs 2500/MT

CD: Critical difference at P=0.05

Weed control
Vidyapeeth, Jalgaon, between 1995 to 1998. The soil characteristics at the experimental site were: pH=8.1 to 8.4, EC=0.38 to 0.40 mmhos/cm, available N=240 to 250, P₂O₅=19.5 to 21.0, and K₂O=652 to 710 kg/ha. The local variety of cowpea was sown. The banana cultivar ‘Basrai’ (AAA) was planted every year in June in 6 m × 6 m plots. In total, there were 32 plots (8 treatments replicated four times) containing 25 plants each. The spacing between plants was 1.5 m × 1.5 m. The experiment was laid out in a randomized block design. The treatments were:

- T₁: Hand weeding
- T₂: Cowpea grown between rows of banana and incorporated into the soil
- T₃: Incorporation of two crops of cowpea into the soil
- T₄: Gramoxone at 1.8 L/ha, 2 to 3 applications depending on weed growth
- T₅: Glyphosate at 2 L/ha followed by Gramoxone at 1.8 L/ha
- T₆: Glyphosate at 2 L/ha followed by Glyphosate at 1.0 L/ha
- T₇: Integrated weed management (T₂ + hoeing and hand weeding)

The soil was uniformly fertilized with 200:40:200 g N:P:K per plant. Growth and yield parameters were recorded. The data from three years were pooled for statistical analysis.

### Results and discussion

Table 1 shows the highest values for pseudostem height, pseudostem girth and total number of leaves per plant were recorded with the integrated weed management treatment (T₇). The second best results came from T₃, the treatment involving the incorporation of two crops of cowpea in the soil. The shortest times to flowering and to harvest were also recorded with this treatment, followed by the integrated weed management. The highest values for the number of hands, number of fingers per bunch, finger length, finger girth and bunch weight were recorded with the integrated weed management treatment followed by T₃. No significant differences were observed between the chemical weed control treatments. The highest bunch weight was recorded with Gramoxone at 1.8 L/ha (T₄), followed by Glyphosate at 2 L/ha + Glyphosate at 1 L/ha (T₆).

The highest yields were observed under the integrated weed management treatment followed by T₇. Results of this investigation are comparable to those observed by Chadha (1999), and Durgadevi and Sathimoorthy (1992). The highest net return per hectare was recorded with integrated weed management (Table 2), suggesting that this was the most efficient method. The next best treatment was T₃.

### Table 1. Effect of various weed control methods on the agronomic performance of ‘Basrai’ (pooled mean of three years 1995-1998).

<table>
<thead>
<tr>
<th>Pseudostem height</th>
<th>Pseudostem girth</th>
<th>Number of leaves (cm)</th>
<th>Days to flowering (cm)</th>
<th>Days to harvesting per plant</th>
<th>Number of hands per bunch</th>
<th>Number of fingers per bunch</th>
<th>Number of length (cm)</th>
<th>Finger girth (cm)</th>
<th>Bunch weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>150.8c</td>
<td>57.7d</td>
<td>29.0c</td>
<td>295a</td>
<td>40a</td>
<td>8.0b</td>
<td>132.1b</td>
<td>19.9c</td>
<td>10.6c</td>
</tr>
<tr>
<td>T₂</td>
<td>158.6b</td>
<td>62.6b</td>
<td>30.9b</td>
<td>296a</td>
<td>377c</td>
<td>8.3b</td>
<td>136.3b</td>
<td>20.4b</td>
<td>11.3b</td>
</tr>
<tr>
<td>T₃</td>
<td>161.5a</td>
<td>65.4a</td>
<td>31.2a</td>
<td>277b</td>
<td>376c</td>
<td>8.8a</td>
<td>142.0a</td>
<td>20.9a</td>
<td>12.0a</td>
</tr>
<tr>
<td>T₄</td>
<td>157.7b</td>
<td>61.0b</td>
<td>30.0b</td>
<td>299a</td>
<td>403a</td>
<td>8.1b</td>
<td>126.3c</td>
<td>20.1c</td>
<td>11.8b</td>
</tr>
<tr>
<td>T₅</td>
<td>154.3b</td>
<td>61.4b</td>
<td>29.9b</td>
<td>290a</td>
<td>380b</td>
<td>7.9b</td>
<td>131.5b</td>
<td>20.1c</td>
<td>11.1c</td>
</tr>
<tr>
<td>T₆</td>
<td>151.7c</td>
<td>59.6c</td>
<td>29.3c</td>
<td>293a</td>
<td>319d</td>
<td>8.2b</td>
<td>129.4c</td>
<td>20.2b</td>
<td>11.2c</td>
</tr>
<tr>
<td>T₇</td>
<td>165.6a</td>
<td>66.5a</td>
<td>31.7a</td>
<td>282b</td>
<td>382d</td>
<td>9.1a</td>
<td>143.5a</td>
<td>21.2a</td>
<td>12.0a</td>
</tr>
<tr>
<td>SE</td>
<td>2.2</td>
<td>0.7</td>
<td>0.4</td>
<td>10.5</td>
<td>16.5</td>
<td>0.2</td>
<td>3.5</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>CD</td>
<td>0.6</td>
<td>2.0</td>
<td>1.1</td>
<td>32.4</td>
<td>50.7</td>
<td>0.5</td>
<td>10.6</td>
<td>0.6</td>
<td>0.8</td>
</tr>
</tbody>
</table>

T₁: Hand weeding
T₂: Cowpea grown between rows of banana and incorporated into soil
T₃: Incorporation of two crops of cowpea into the soil
T₄: Gramoxone at 1.8 L/ha, 2-3 spray depending upon weed growth
T₅: Glyphosate at 2 L/ha, followed by Gramoxone at 1.8 L/ha
T₆: Glyphosate at 2 L/ha, followed by Glyphosate at 1.0 L/ha
T₇: Integrated weed management (T₂ + hoeing and hand weeding)

### Table 2. Effect of weeding on the yield and economic performance of ‘Basrai’ bananas

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (MT/ha)</th>
<th>Total cost (Rs)</th>
<th>Income/ha (Rs)</th>
<th>Net income/ha (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>62.96</td>
<td>46.188</td>
<td>158.900</td>
<td>108.712</td>
</tr>
<tr>
<td>T₂</td>
<td>67.89</td>
<td>45.911</td>
<td>169.752</td>
<td>123.814</td>
</tr>
<tr>
<td>T₃</td>
<td>73.77</td>
<td>47.591</td>
<td>184.425</td>
<td>136.834</td>
</tr>
<tr>
<td>T₄</td>
<td>66.22</td>
<td>44.737</td>
<td>165.550</td>
<td>120.813</td>
</tr>
<tr>
<td>T₅</td>
<td>64.13</td>
<td>44.771</td>
<td>160.325</td>
<td>115.554</td>
</tr>
<tr>
<td>T₆</td>
<td>65.10</td>
<td>44.789</td>
<td>162.750</td>
<td>117.961</td>
</tr>
<tr>
<td>T₇</td>
<td>78.35</td>
<td>48.188</td>
<td>195.875</td>
<td>147.687</td>
</tr>
</tbody>
</table>

See Table 1 for information on treatments; Daily labour cost: Rs 30; Price of bananas: Rs 2500/MTR
An integral method for estimating total leaf area in bananas
D. W. Turner

A method that measures total leaf area of banana plants quickly and accurately would be widely adopted. Kumar et al. (2002) proposed such a method based on a measurement of the area of the third most recently emerged leaf and the number of leaves present on the plant.

My aim here is to show, firstly, that the 'new factor', suggested by Kumar et al. (2002), is restricted by the assumptions on which it is based. Secondly, I wish to propose an integral method that requires two leaves to be measured, but which avoids the problems I perceive exist in the new factor method. Thirdly, I compare the two methods on a limited set of data to illustrate the issues and to show the expected errors in using the two equations.

The ‘new factor’ method
The formula that Kumar et al. (2002) proposed to estimate total leaf area of a single plant was:

\[ TLA = B \times 0.80 \times N \times 0.662 \]  

where \( TLA \) is the total leaf area of the plant, \( N \) is the number of leaves on the plant (and also the leaf number of the youngest leaf when leaves are numbered from the oldest (leaf 1) to the youngest (leaf N) as is the case in this paper), \( L \) and \( B \) are the length and breadth of the third youngest leaf (\( A_{N-3} \)), and 0.8 is the proportionality factor proposed by Murray (1960). The new factor is the coefficient with the value of 0.662. To derive the new factor, Kumar et al. (2002) used 25 plants on which they measured \( A_{N-3} \) and \( N \) to calculate, using the 0.80 factor, the estimated total leaf area and they measured the actual total leaf area (\( A_m \)) using a leaf area meter. For each of the 25 plants, the ratio of the actual total leaf area to the estimated total leaf area was calculated and the mean of these values gave the new factor 0.662. This new factor was then used to calculate the total leaf area for each of the 25 plants that had been used to derive it and, not surprisingly, the authors found very good agreement.

Since the new factor of 0.662 was locally derived, extension to other situations may give incorrect estimates of leaf area per plant. The new factor is also determined by the relationship between the size of the third youngest leaf and the remainder of the leaf system, and this can be expected to change during plant ontogeny. Kumar et al. (2002) do point out that leaf size varies during development and also add that the new factor was derived to take this into account.

Mathematically the new factor is derived from \( (A_m/N)A_{N-3} \) in which \( A_m/N \) is the arithmetic mean area per leaf. Therefore, the calculation of the new factor assumes that the increase in leaf area from leaf to leaf during plant ontogeny is linear because it uses the arithmetic mean for its derivation. However, a plot of the increase in leaf area against leaf number during plant ontogeny (Figure 1.15 in Stover and Simmonds, 1987) reveals that the increase in area is not linear but exponential over at least 75% of the plant’s vegetative cycle, i.e. the exponential phase ends at leaf 30, after which the leaves are of similar size until leaf 42.

The new factor will be influenced by the exponential nature of the increase in leaf area, number of leaves used in the calculation and plant stage. If the new factor is calculated by using the leaves of the exponential phase, it will decrease from 1.2 to 0.4 as the number of leaves included in the calculation increases from 3 to 30. If the leaves that have reached a plateau are used to calculate the new factor, its value will be 1.0 and the number of leaves included...
will have no effect. Since experimental treatments such as fertilizer or irrigation will also influence the leaf system, the new factor is likely to be influenced by treatment and so the use of a single value could give misleading results.

A credible method for estimating the leaf area of a whole plant needs to take account of 1) the exponential nature of the increase in leaf area from one leaf to the next, 2) the change from one growth phase to another, and 3) the variable number of leaves.

The integral method

If the area of each leaf in a given ontogenetic sequence increases exponentially then a plot of the area of each leaf against leaf number becomes linear if leaf area is log-transformed. This can be described using the equation:

\[ A_n = A_0 e^{Rn} \quad (2) \]

where \( A_n \) is the area of the nth leaf, \( A_0 \) is the area of the initial leaf, \( R \) is the relative rate of increase in leaf area that quantifies the increase in area from one leaf to the next. \( R \) is calculated as follows:

\[ R = \frac{(\ln A_N - \ln A_i)}{(N-1)} \quad (3) \]

where \( A_N \) is the area of the youngest leaf and \( A_i \) is the area of the oldest green leaf on the plant.

To estimate the leaf area between any two leaves on a plant, the area under the curve formed by equation (2) can be determined by integration with respect to \( N \):

\[ A_{i,N} = A_i \left[ \frac{(\exp(RN) - \exp(Ri))}{R} \right] \quad (4) \]

\( A_{i,N} \) is the integration of the leaf areas between leaf \( i \), the oldest leaf at the time of measurement, and leaf \( N \), the youngest leaf. \( A_i \) is the area of the oldest leaf on the plant. To implement the integral method for estimating leaf area on a plant, measurements of the areas of \( A_i \) and \( A_N \) are required. The value of \( R \) is then calculated. Leaf \( i \) can be taken as 1 and \( N \) represents the number of green leaves on the plant.

\( R \) is likely to vary with factors such as cultivar, water or nutrient supply environment or stage of plant ontogeny. Because \( R \) is estimated for each plant, the effect of an experimental treatment on \( R \) is automatically taken into account in the estimation of total leaf area, making the integral method adaptive. The integral method and the new factor proposed by Kumar et al. (2002) can now be compared.

Test of the integral method

The data set used for the comparison of the methods is a simulated reconstruction of the data in Fig 1.15 of Stover and Simmonds (1987). Leaf 1 was set at 100 cm\(^2\) and the area of each leaf was incremented by 20% of the area of the preceding leaf. Thus:

\[ A_n = A_{n-1} + 0.2(A_{n-1})e^N \quad (5) \]

For leaves 31 to 42, the area was fixed at 17 000 cm\(^2\) per leaf.

The total area of any consecutive number of leaves within the range 1 to 42 was added to provide the actual area. This would be the same as measuring the area of every leaf present on a plant and then summing them. The estimates of the area using the new factor and the integral method were compared with the actual area. The difference between the actual area and the area obtained with each method was then expressed as a percentage (Figures 1a and 1b).

In Figure 1a, the effect of increasing the number of leaves included was examined by starting with the first three leaves and then ending with leaves 1 to 42 included. For example, the third youngest leaf used in the new factor calculation would be leaf 1, when only three leaves are included, and leaf 40, when all 42 leaves are included. The third youngest leaf is incremented as \( N \) increases. This approach allows us to see how each method deals with plants that have a very different number of leaves. These calculations go well beyond the maximum number likely to be found in the field.

In figure 1b, the number of leaves was fixed at 14, which is the mean leaf number in the population used by Kumar et al. (2002) to derive the new factor and, as such, likely to provide the ‘best’ evaluation of this method. Sequences of 14 consecutive leaves were selected by adding one to advance the sequence and subtracting one to maintain the number of leaves at 14. Thus the first sequence included leaves 1 to 14 and the last sequence included leaves 29 to 42. For each situation, the leaf areas were calculated in an Excel® spreadsheet using the actual area, and the new factor and integral methods.

In the exponential phase of leaf area increase, and as the number of leaves included in the assessment increased from 3 to 42, the new factor method initially underestimated total leaf area by almost 50% (Figure 1a). Then the estimates were closer to the actual area until they were similar at 13
to 14 leaves. As more leaves were included, the new factor method overestimated leaf area and reached its greatest discrepancy at the end of the exponential phase at 31 leaves. The reason for this trend is the changing discrepancy between the value of the new factor fixed at 0.662 and its actual value, which decreases from 1.2 to 0.4 as the number of leaves increased. Since leaves 30 to 42 are the same size, their inclusion forced the new factor up again towards 0.662, bringing the estimates of leaf area closer to the actual.

In contrast, the integral method was more accurate than the new factor method, especially in the exponential phase. It underestimated the actual leaf area by about 20% at 3 leaves (Figure 1a). As the number of leaves increased, the integral method approached the actual area and was similar to it at 6 to 7 leaves. Then, as the number of leaves reached 29 leaves, the integral method overestimated the actual area by less than 10%. Because the integral method included the change in R as the number of leaves increased, the method was better able to estimate the total leaf area and as a result tracked closely the actual area (Figure 1a). Beyond the exponential phase, the inclusion of the leaves that were not increasing exponentially in area from one leaf to another changed the estimation of R and the estimates of the area deviated from the actual area.

When a sequence of 14 leaves was moved progressively through plant ontogeny, both the new factor method and the integral method overestimated leaf area but the integral method was closer to the actual values, especially in the exponential phase (Figure 1b). Again, the inclusion of leaves beyond the exponential phase, caused each method to deviate. The integral method gave better estimates than the new factor method because it accounted for the exponential change in leaf area during plant ontogeny and the calculation of R was based on the leaves being measured.

Neither method deals with the change in ontogeny to the plateau phase where leaves are the same size. The integral method assumes an exponential increase in leaf area throughout ontogeny but it can be adapted to the case of linear increase by including the measurement of two leaves, which would make it more adaptive than the new factor method. If the change can be detected, then the number of leaves in the plateau phase can be counted and the total area of these leaves added to the estimations of the integral method. An addition to equation (4) and a change of terms is needed to achieve this:

$$A_{N_p} = A_1[(\exp(RN_e) - \exp(Ri))/R] + A_{N_p}$$

(6)

where, if $A_1$ is the area of the first leaf in the plateau phase, then only two leaves need be measured as before. $N_e$ is the number of leaves included in the exponential phase and $N_p$ is the number of leaves in the plateau phase.

References


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Performance of introduced cultivars under different farming conditions in north-western Nicaragua

S. Coessens, M. Tshiuza, M. Vargas, E. Tolleens and R. Swennen

Since 1997, the Universidad Nacional Autónoma de Nicaragua (UNAN) with support of the Vlaamse Vereniging voor Ontwikkelingshulp en Technische Bijstand (VVOB) and the company Bananic, and in partnership with 20 national and international programmes, has been testing and distributing new cultivars of bananas and plantains in north-western Nicaragua. The intervention aims to improve the food security of resource-poor farmers. The strategy and mode of operation of this intervention have been described by Dens et al. (2002). So far, 16 cultivars and improved hybrids (‘Rose’, FHIA-01, FHIA-02, FHIA-03, FHIA-17, ‘Pelipita’, ‘Pisang Ceylan’, ‘Pisang lidi’, ‘Pisang mas’, TMBx 1378, TMBx 5295, TMPx 1621, TMPx 4479, TMPx 7002, TMPx 7152 and ‘Yangambi km 5’) have been introduced and 68,700 in vitro plantlets have been produced locally and distributed to more than 1000 small and medium-sized farmers.

The specific objectives of this paper are 1) to determine the major farming systems practiced by small and medium-sized farmers in the area under study and the importance of traditional cultivars within each system, 2) to evaluate the performance of the introduced cultivars and 3) to draw lessons about the factors that are important for a successful introduction in order to guide further collaboration with farmers (Coessens 2002).

### Typology of farming systems

The classification criteria used in this study are 1) the major farming activity practiced by the farmer, i.e. crop production or animal production, 2) the major water source for crop production, i.e. irrigation or rainfall, and 3) the farmer’s production objective, i.e. subsistence or commercial. The ensuing 8 farming systems are named after the major water source in the production system, the major farming activity and the main destination of its production. The importance of bananas and plantains is summarised in Table 1.

The study was limited to 252 farms who had received new cultivars as in vitro material in the year 2000. They are in the region Léon-Chinandega, where the annual rainfall varies between 1142 mm and 1927 mm over a 6-month period (MAGFOR 1999).

### Irrigated cash plantain farming system (FS1)

In this system, banana and plantain production represents the major agricultural activity, practiced mostly in monoculture. Its cultivation benefits from sprinkler or gravity irrigation, supported by motor pumps. This system is found in plains and zones where the water table has an average depth of 9 m. The banana fields are generally located along or near tarmac roads, as the fruits are usually meant for the local market. The average land area planted with banana and plantains is 1.3 ha, which represents about 32% of the total land area of the farm, while the average density is 1474 plants/ha.

### Table 1. Typology of the various farming systems and the importance of bananas and plantains

<table>
<thead>
<tr>
<th>Farming systems</th>
<th>Major farming activity</th>
<th>Major source of water</th>
<th>Production objective</th>
<th>Percentage of farmers (%)</th>
<th>Mean area dedicated to bananas and plantains (ha/farmer)</th>
<th>Average density plants (plants/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS1</td>
<td>plantain</td>
<td>irrigation</td>
<td>commercial</td>
<td>2.0</td>
<td>1.3</td>
<td>1474</td>
</tr>
<tr>
<td>FS2</td>
<td>plantain</td>
<td>irrigation</td>
<td>commercial</td>
<td>1.6</td>
<td>1.3</td>
<td>1448</td>
</tr>
<tr>
<td>FS3</td>
<td>other crops</td>
<td>irrigation</td>
<td>commercial</td>
<td>5.2</td>
<td>0.4</td>
<td>703</td>
</tr>
<tr>
<td>FS4</td>
<td>livestock</td>
<td>irrigation</td>
<td>commercial</td>
<td>3.6</td>
<td>0.6</td>
<td>1147</td>
</tr>
<tr>
<td>FS5</td>
<td>other crops</td>
<td>irrigation</td>
<td>subsistence</td>
<td>7.1</td>
<td>0.1</td>
<td>1020</td>
</tr>
<tr>
<td>FS6</td>
<td>other crops</td>
<td>rainfall</td>
<td>commercial</td>
<td>32.1</td>
<td>0.4</td>
<td>463</td>
</tr>
<tr>
<td>FS7</td>
<td>livestock</td>
<td>rainfall</td>
<td>commercial</td>
<td>8.3</td>
<td>0.2</td>
<td>715</td>
</tr>
<tr>
<td>FS8</td>
<td>other crops</td>
<td>rainfall</td>
<td>subsistence</td>
<td>40.1</td>
<td>0.1</td>
<td>500</td>
</tr>
</tbody>
</table>
farm. Other crops found in this system are maize, rice, vegetables, sugarcane and sorghum. Farmers also have some cattle and/or small livestock.

**Rainfed cash plantain farming system (FS2)**
This system is similar to FS1 but banana and plantain production depends on rainfall. This farming system is found in plains, inland valleys and humid zones, where the water table lies at an average depth of about 4 m. The average land area devoted to bananas and plantains, grown mostly in monoculture, is 1.3 ha (11% of total land area), while the average density is 1448 plants/ha. As in FS1, only a few farmers (1.6%) practice this system and use mostly family and temporary labour. Maize and rice are also cultivated, mainly for home consumption.

**Irrigated system with other cash crops (FS3)**
In this system, irrigation provides the major water source to various crops grown mostly for sale. This system is found in plains and zones with an average water table depth of 10 m. It is practiced by only 5.2% of farmers, using family labour as well as temporary and permanent workers. Irrigation depends on motor and rope pumps (gravity irrigation). Irrigated crops are mostly staple foods (maize, rice, beans, sorghum) and vegetables. Other crops grown in this system are cassava and soybean. Some farmers irrigate small areas of bananas and plantains grown sometimes in association with other crops like vegetables or small fruit trees. The average land area allocated to bananas and plantains is 0.4 ha, which is 6% of total land under cultivation, at an average density of 703 plants/ha. Farmers also own a few cows.

**Irrigated system with cash livestock (FS4)**
Animal production is the major activity practiced by farmers (3.6%) in this system, using family labour as well as temporary and permanent workers. Farmers own both cattle and small livestock, the former for sale and the latter for home consumption. This system is found in plains and zones with an average water table depth of 9 m.

In addition to animal production, farmers grow maize, rice, beans, vegetables, sesame and bananas and plantains (in monoculture or associated with vegetables), using sprinkler and drip irrigation systems. Some farmers are also involved in agroforestry activities. The average land area planted with banana and plantains is 0.6 ha, which represents 2% of the total area under cultivation, at an average density of 1147 plants/ha.

**Irrigated system with subsistence crops (FS5)**
This system comprises farmers (7.1%) who use irrigation and family labour in order to produce crops for home consumption. It is found in less accessible zones, on hills and in dry regions with a pronounced dry spell – 20 to 30 consecutive days without rain during the rainy season, mostly in July-August (MAGFOR 1999) – and with a water table at an average depth of 13 m. The major crops grown in this system are maize, sorghum, cassava, vegetables, sesame and sometimes bananas and plantains (in association with vegetables). Vegetables, grown on an average area of 0.1 ha, are the major crops irrigated in this system. The average area planted with bananas and plantains is 0.1 ha and represents about 7% of the total land area. The average density is 1020 plants/ha.

**Rainfed system with other cash crops (FS6)**
Rainfall is the main source of water for the production of cash crops. This system is practiced by many farmers (32.1%) using mostly family and temporary labour. It is found in zones that vary in accessibility, humidity and topography, and where the water table is at an average depth of 27 m. The major crops grown in this system are maize, rice, cassava, soybean and vegetables. The products are sold on the farm or at city markets. Some farmers also grow plantains and bananas as a secondary crop, in association with vegetables, for home consumption. The average area devoted to plantains and bananas is 0.4 ha, i.e. 4% of the total cultivated area, while the average density is 463 plants/ha.

**Rainfed system with cash livestock (FS7)**
Cattle production is the major activity in this system. It is practiced by about 8.3% of farmers using family labour, temporary and permanent workers. The water table is at an average depth of 22 m. Secondary farming activities include maize, rice and vegetables, sometimes associated with bananas and plantains. The average area used for banana and plantain production is
0.2 ha and represents only 1% of the land under cultivation. The average density is 715 plants/ha.

Rainfed system with subsistence crops (FS8)

This system, which is practiced by the majority of farmers (40.1%) using family labour, is found in less accessible and less favourable areas, on hills and regions where the water table is at an average depth of 25 m. Rainfall is the main source of water used in the production of crops (mostly maize) generally directed to home consumption. Farmers also own small livestock for home consumption. Other minor crops grown in this system may include rice, vegetables, sesame, sorghum, beans, cassava, fruit and bananas and plantains (generally planted in association). The average area devoted to bananas and plantains is 0.1 ha, or 3% of the land under cultivation, while the average density is 500 plants/ha. In this system, farmers frequently work as salaried labourers for other farmers or in non-farming activities.

On-farm evaluation of the introduced cultivars

The survival and harvest of the banana cultivars was evaluated 1.5 years after their introduction. The proportion of plants that survived is the number of growing and harvested plants relative to the number of plants introduced or donated, while the proportion harvested is the number of plants harvested relative to the number of plants introduced or donated. From a total of 14 000 plants planted in 252 plots, 23% had been harvested, 23% were still growing, while 54% had been lost due to drought, wind damage, animal damage or other unknown reasons. The average amount of plants per plot was 56, with a minimum of 10 and a maximum of 400.

Both survival and harvest percentages of the introduced bananas and plantains vary from one farming system to another and both rates were higher under irrigation (Table 2 and Figure 1). In the irrigated systems survival and production rates varied with the type of irrigation system practised.

### Table 2. Performance of introduced bananas and plantains under different farming systems (FS)

<table>
<thead>
<tr>
<th>Farming systems</th>
<th>Survived (%)</th>
<th>Harvested (%)</th>
<th>Lost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS1*</td>
<td>79</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>FS2</td>
<td>61</td>
<td>55</td>
<td>39</td>
</tr>
<tr>
<td>FS3*</td>
<td>60</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td>FS4*</td>
<td>89</td>
<td>41</td>
<td>11</td>
</tr>
<tr>
<td>FS5*</td>
<td>67</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>FS6</td>
<td>29</td>
<td>15</td>
<td>71</td>
</tr>
<tr>
<td>FS7</td>
<td>41</td>
<td>25</td>
<td>59</td>
</tr>
<tr>
<td>FS8</td>
<td>27</td>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>Mean</td>
<td>46</td>
<td>23</td>
<td>54</td>
</tr>
</tbody>
</table>

* Irrigated

### Figure 1. Performance of introduced plants in relation to the source of water.

<table>
<thead>
<tr>
<th>% of total plants</th>
<th>Irrigated</th>
<th>Rainfed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
<td>30</td>
</tr>
</tbody>
</table>

### Figure 2. Performance of introduced plants in relation to the water supply system.

<table>
<thead>
<tr>
<th>% of total plants</th>
<th>Motor pump</th>
<th>Rope pump</th>
<th>Oxen or horse drawn pump</th>
<th>Manual</th>
<th>Without well</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>75</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

### Figure 3. Performance of introduced plants in relation to the type of irrigation.

<table>
<thead>
<tr>
<th>% of total plants</th>
<th>Bucket</th>
<th>Hose</th>
<th>Gravity irrigation</th>
<th>Sprinkler irrigation</th>
<th>Without irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90</td>
<td>75</td>
<td>60</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

Legends for figures 1 to 5:

- Lost plants
- Plants that survived
- Harvested plants
The best results were obtained with motor pumps, gravity and sprinkling systems when more water can be brought close to the plants (Figures 2 and 3). Bananas and plantains demand a lot of water and are very sensitive to sudden changes in the soil’s water content. On a sunny day, a banana plant consumes an average of 20 litres of water (Belalcazar 1991). It also has little capacity to absorb water from a soil drying out, which makes the maintenance of a high soil humidity imperative. The importance of water for the survival of banana and plantain plants is stressed by the results obtained in loamy soils compared with other types of soil (Table 3). Loamy soils have a good drainage and can make water more easily available to plants than other soil types. Sandy soils dry out quickly while clay soils do not release their water easily.

The percentage of lost plants is also affected by the location of plots in relation to the farmer’s homestead. Plots established in farmers’ backyards (patios) suffered more damages from small livestock than those planted in fields (Table 3). Finally, survival was higher in bananas belonging to farmers who received the most in vitro plantlets from the project (Figure 4). This is probably due to the fact that those farmers who asked to receive more plant material were also the most motivated to evaluate the new germplasm. Figure 5 illustrates this point, but indicates also that those farmers who had more banana and plantain plants to start with were more successful because they were operating under better banana and plantain cropping conditions (climate, soil fertility, pests and diseases, market, etc).

Conclusion
Bananas and plantains were found in all the farming systems, but were predominant in only 2 (FS1 and FS2), representing 3.6% of the population under study. These results suggest that there is room for the expansion of this crop within all the farming systems of the region and that the diversity of their farming conditions has to be taken into consideration prior to any intervention at the farm level.

In this respect, the results of the on-farm evaluation of the introduced cultivars indicate that the most important factors for a successful introduction, and production, of new germplasm in this rather dry region include access to water, utilisation of fields (instead of patios) and type of soil. The study shows the importance of involving in the early stages of the introduction of new germplasm the farmers who already grow bananas and plantains.

Acknowledgements
The authors want to acknowledge the assistance of Lic. Magaly Ruiz, Lic. Bismark Rodriguez and Ing. Kristien De Waele for their contribution to the collection and analysis of the data. The authors are also grateful to UNAN for their logistical support, the VVOB for the salary of S.C and the

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Survived (%)</th>
<th>Harvested (%)</th>
<th>Lost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>41</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>Sand-loam</td>
<td>46</td>
<td>19</td>
<td>54</td>
</tr>
<tr>
<td>Loam</td>
<td>53</td>
<td>28</td>
<td>47</td>
</tr>
<tr>
<td>Clay-loam</td>
<td>50</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>Clay</td>
<td>24</td>
<td>10</td>
<td>76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field location</th>
<th>Survived (%)</th>
<th>Harvested (%)</th>
<th>Lost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close to the house (patio)</td>
<td>42</td>
<td>17</td>
<td>58</td>
</tr>
<tr>
<td>Far away (in a field)</td>
<td>57</td>
<td>30</td>
<td>43</td>
</tr>
</tbody>
</table>

Figure 4. Performance of introduced plants in relation to the amount of in vitro plants received from the project.

Figure 5. Performance of introduced plants in relation to the number of banana and plantain plants already grown by the farmer.

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Characterization of the growth and production of some plantain hybrids and cultivars in Colombia

John Willans Herrera M. and Manuel Aristizábal L.

In Colombia, plantain (Musa AAB) is of great social, economic and culinary importance. The varieties that are cultivated are adapted to the temperature at various altitudes: Hartón (Musa cv. AAB) between 0 and 1000 metres above sea level, ‘Dominico hartón’ (Musa cv. AAB) between 1000 and 1400 masl and ‘Dominico’ (Musa cv. AAB) between 0 and 2000 masl (Belalcázar et al. 1998). Cultivation is on 400 000 ha, with a production of 2 970 000 ton/year, of which 96% is for home consumption and 4% for export (Lescot and Grisales 1992). From 1992 to 1998, the average yield fell from 7.2 to 6.8 ton/ha representing an average annual reduction of 0.8%, due mainly to diseases such as black leaf streak disease (caused by Mycosphaerella fijiensis Morelet) and Sigatoka disease (caused by Mycosphaerella musicola Leach) (CCI 1999), the main threats worldwide to production of plantain and banana (ICA 1996).

‘Dominico hartón’ is highly susceptible to the Sigatoka diseases and since there is as yet no resistant variant of this cultivar, resistant hybrids have been cultivated for some years. However, there has been no systematic evaluation of their growth, development and production (ICA 1996). This is the case of the FHIA (Fundación Hondureña de Investigación Agrícola) hybrids, some of which have yields of 16.7 ton/ha in comparison with 6.7 ton/ha for traditional varieties (CCI 1999), but whose agronomic performance has not been adequately evaluated (Belalcázar et al.1998). This lack of data limits their potential as alternatives in commercial plantations.

The objective of the present work was to evaluate the agronomic behaviour of the plantains ‘África’ (Musa cv. AAB), ‘Dominico hartón’, ‘FHIA-20’ and ‘FHIA-21’ in the ecological conditions of the Santángueda (Palestina, Caldas) region, and hence to identify those with the highest productivity.

Materials and methods

The study was carried out on the Montelindo farm, owned by Caldas University and located in the Municipality of Palestina (Caldas), 5°05 latitude north and 75°40 longitude west, at an altitude of 1050 masl; the average temperature is 22.8°C, relative humidity is 76%, annual rainfall 2100 mm and the soils are of volcanic origin, classified as ‘Typic Distrandept’.

Plots were established according to a completely randomized design with 5 replicates, and contained a total of 25 plants each, with 2 m between plants and 3 m between rows. Each plot was surrounded by plants of ‘Dominico hartón’ to provide an abundant source of inoculum. The planting materials were plantlets of ‘FHIA-20’ and ‘FHIA-21’ donated by the FHIA as in vitro plantlets and multiplied in the tissue culture laboratory, Caldas University.

Agronomic management was as needed and included: fertilization, desuckering, removal of dry material from the pseudostem, deleafing, removal of necrotic leaf tip, removal of male bud, bagging and control of weeds. At planting, each plant hole...
received 1 kg of an ash-based compost, 3 g Carbofuran, 10 g MgO and 3 g Borax. Fertilisers were applied a total of three times at intervals of 4 months: first application - 200 g per plant NH₄NO₃ + KCl (ratio 1:1), second application - Cumba (15-4-23-4), third application - NH₄NO₃ + KCL (ratio 1:1). Fungicides were not applied.

At flowering, plant height, pseudostem girth at 1 m from the base of the plant, number of emerged leaves, number of functional leaves at flowering (i.e. those that are erect and have at least 75% of their area that is green), and days to flowering. At harvest, measurements were taken of the number of functional leaves at harvest, days from flowering to harvest, days to harvest, total number of fingers, number of fingers in the first and second hands, weight of the first and second hands, total bunch weight, and diameter, length and weight of the central finger of the second hand.

An analysis of variance was performed using the PROC MIXED model of the statistical program SAS (Statistical Analysis System). The data were transformed by means of the formula 0.05 + √x. Comparison of means was by the Tukey test at a significance of P = 0.05.

**Results and discussion**

**Characteristics of growth and development**

Significant differences were observed for plant height and pseudostem diameter between ‘FHIA-20’ and the remaining materials. Similarly, differences were observed between ‘FHIA-21’ and ‘Dominico hartón’ for pseudostem diameter. Plant height and pseudostem diameter became steady in ‘FHIA-20’, ‘FHIA-21’, ‘Africa’ and ‘Dominico hartón’ from weeks 43, 51, 39 and 43 respectively, thus demonstrating the earliness of ‘Africa’ material. ‘Dominico hartón’ and ‘FHIA-20’ showed the highest number of emerged leaves, with means of 37 and 36 leaves respectively; ‘Africa’ had the lowest number of emerged leaves, the value being associated with the shortest vegetative cycle (Table 1).

‘FHIA-20’ had the highest number of functional leaves at flowering. ‘Dominico hartón’ had the lowest mean number of functional leaves at harvest even though it had the highest number of emerged leaves and at flowering had a large number of functional leaves (Table 1). Over time, ‘FHIA-20’ maintained a higher number of functional leaves in comparison with the other materials, possibly due to differences in reaction to black leaf streak disease, differences in leaf longevity or differences in rates of leaf emergence. In general, materials maintained a high number of functional leaves to flowering, suggesting that defleeting and removal of necrotic tips helps maintain the functional leaf area. The number of functional leaves over time is a function of the relationship between the rates of leaf emergence and abscission, which in turn determine the number of leaves that the plant has at the time of flowering (Aristizábal et al. 1988), providing plants do not suffer from lack of water, disease or nutrient deficiency.

In the study zone, black leaf streak disease is a permanent biotic component. Castaño-Zapata (pers. com.) observed that, in the same zone, disease severity at harvest was 27% for ‘FHIA-20’, 58% for ‘FHIA-21’ and 98% for ‘Dominico hartón’; similarly, although hybrids also lost leaves during bunch filling, their degree of resistance to black leaf streak disease and the larger size of individual leaves, meant that the area of necrotic tissue was less than in ‘Dominico hartón’. This behaviour is also associated with the low yield of the local cultivar as concluded by Martínez (1984) with a minimum requirement of eight leaves.

### Table 1. Growth characteristics and development of plantain materials in the Santágueda region (Colombia). Mean and min-max (n=125)

<table>
<thead>
<tr>
<th>Material</th>
<th>Plant height (m)</th>
<th>Diameter of pseudostem (cm)</th>
<th>Days to harvest</th>
<th>Days to harvest</th>
<th>Emerged leaves</th>
<th>Functional leaves at flowering</th>
<th>Functional leaves at harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-20</td>
<td>3.7 a (3.3-4.2)</td>
<td>23 a (19-28)</td>
<td>300b (252-406)</td>
<td>423 b (350-504)</td>
<td>35 ab (29-44)</td>
<td>12 a (9-14)</td>
<td>3 c (1-7)</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>3.3 b (3.3-3.9)</td>
<td>19 c (17-21)</td>
<td>355 a (308-434)</td>
<td>462 a (406-518)</td>
<td>36 ab (29-40)</td>
<td>9 bc (6-10)</td>
<td>4 a (0-5)</td>
</tr>
<tr>
<td>África</td>
<td>3.4 b (3.1-3.7)</td>
<td>18 bc (15-21)</td>
<td>274 c (238-336)</td>
<td>367 c (338-420)</td>
<td>32 b (27-37)</td>
<td>8 c (2-11)</td>
<td>3 ac (0-6)</td>
</tr>
<tr>
<td>Dominico hartón</td>
<td>3.4 b (3.1-3.7)</td>
<td>17 b (16-19)</td>
<td>303 b (266-350)</td>
<td>411 b (375-434)</td>
<td>37 a (33-41)</td>
<td>9 b (6-10)</td>
<td>1 b (0-3)</td>
</tr>
</tbody>
</table>

* Mean values in the same column followed by different letters indicate significant differences according to Tukey’s comparison of means at 5%.
at flowering to obtain high yields, providing that functional leaves are maintained during bunch filling. The above reflects the effects of loss of functional leaves after flowering on the low yield in the cultivar Dominico hartón, as reported by Cayón and Bolaños (1999). The number of functional leaves at harvest is a good indicator of resistance or susceptibility to black leaf streak disease, and there is a positive correlation between the number of functional leaves at harvest and bunch weight (álvarez 1997).

'FHIA-21' was the slowest of the materials to flower and to reach harvest, followed by 'FHIA-20', 'Dominico hartón' and 'África'. Bunch filling was slowest in 'FHIA-20' and fastest in 'África'. Analysis of the range of values revealed that the largest variability was observed for days to flowering and to harvest, whilst plant height was the least variable.

Characteristics of the bunch

The largest total bunch weights were obtained with the hybrids, being significantly higher than the local cultivars (Table 2), possibly because of the environmental conditions and more particularly their tolerance of black leaf streak disease. In particular, 'FHIA-20' had the best agronomic behaviour, as already shown with significantly higher values of variables that characterize yield with the exception of bunch diameter, length of the middle finger and weight of middle finger, both of the second hand, and whose highest values were found in the variety 'África'. On average, 'FHIA-21' had significantly shorter fingers in comparison with other materials, between which differences were not significant.

Although the local material is susceptible to the Sigatoka diseases, and as a result yields are not the highest, the agronomic behaviour was within the ranges reported for the coffee producing zone (Arango 1987).

In general, the hybrids produced bunches with the highest number of fingers but this was also the most variable of the parameters contrary to the values observed with 'África' and 'Dominico hartón'. Similarly, total bunch weight was less variable in the varieties than in the hybrids although, in the latter, bunches of more than 33 kg were recorded (Table 2).

References


Table 2. Caracteristics of the bunch during the first cycle of evaluation of plantain materials in the Santágueda region (Colombia).

<table>
<thead>
<tr>
<th>Material</th>
<th>Number of fingers in the first hand</th>
<th>Weight of the first hand (kg)</th>
<th>Number of fingers in the second hand</th>
<th>Weight of the second hand (kg)</th>
<th>Total number of fingers</th>
<th>Weight of the middle finger of the second hand (g)</th>
<th>Length of the middle finger of the second hand (cm)</th>
<th>Diameter of the middle finger of the second hand (cm)</th>
<th>Total weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-20</td>
<td>19 a</td>
<td>8.9 a (5.8-12.2)</td>
<td>16 a</td>
<td>7.2 a (4.8-9.2)</td>
<td>103 a (70-148)</td>
<td>502 a</td>
<td>25.8 a</td>
<td>4.8 b</td>
<td>40.0 a (25.7-49.2)</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>16 b</td>
<td>3.4 b (1.8-5.8)</td>
<td>13 b</td>
<td>2.8 c (1.4-5.1)</td>
<td>74 b (53-114)</td>
<td>235 b</td>
<td>17.9 b</td>
<td>3.4 c</td>
<td>17.0 b (10.2-33.1)</td>
</tr>
<tr>
<td>África</td>
<td>7 d</td>
<td>4.3 bc (1.9-6.9)</td>
<td>7 d</td>
<td>3.7 b (2.0-4.7)</td>
<td>25 c (14-30)</td>
<td>513 a</td>
<td>26.4 a</td>
<td>5.5 a</td>
<td>14.8 b (12-8-20.4)</td>
</tr>
<tr>
<td>Dominico hartón</td>
<td>11 c</td>
<td>5 c (2.6-6.4)</td>
<td>10 c</td>
<td>4.1 b (2.1-5.5)</td>
<td>45 c (23-57)</td>
<td>446 a</td>
<td>25.9 a</td>
<td>5 ab</td>
<td>19.2 b (12.1-26.3)</td>
</tr>
</tbody>
</table>

* Mean values in the same column followed by different letters are significantly different at 5% according to Tukey’s test for the comparison of means.
Sigatoka disease (caused by Mycosphaerella musicola Leach) and black leaf streak disease (caused by Mycosphaerella fijiensis Morelet) are the most important leaf diseases in plantain and banana. There are two types of plant resistance to disease. In the first, the host resists establishment of the parasite by restricting the infection process; the resistance is called specific or vertical resistance (Nelson 1977). This type of resistance can be introduced relatively easily in cultivars and its effects are obvious, one of the reasons why plant improvement tends to be based on vertical resistance (Castaño-Zapata 2002).

In the second type of resistance, the host resists colonisation by the parasite, a process called horizontal or non-specific resistance (Nelson 1977). This type of resistance reduces the disease development rate. It is relatively difficult to introduce because of the complexity of its heritability and its regulation by many genes (Castaño-Zapata 2002).

The Fundación Hondureña de Investigación Agrícola (FHIA) has developed hybrids resistant to the main diseases. For example, ‘FHIA-21’ is a plantain resistant to black leaf streak disease, and ‘FHIA-01’ and ‘FHIA-17’ are bananas respectively resistant and tolerant to black leaf streak disease (FHIA 1993). This investigation aimed to obtain information on the resistance of the hybrids ‘FHIA-01’, ‘FHIA-17’ and ‘FHIA-21’, and of the cultivars ‘Gros Michel’ and ‘Dominico hartón’, to the diseases caused by M. fijiensis and M. musicola.

Materials and methods
The controlled phase took place in a nursery located on the Montelindo farm and equipped with a mister activated by a TC-1800 LX II control unit. The response to the diseases was evaluated by means of artificial inoculations with Paracercospora fijiensis and Pseudocercospora musae, the anamorphs of M. fijiensis and M. musicola, respectively.

Diseased leaves were maintained for 48 hours in plastic bags to stimulate the discharge of ascospores (Du Pont 1982). After incubation, tissues were cut into pieces of approximately 4 cm² each, numbered 1 to 5 and attached to circles of filter paper 9 cm in diameter. Each filter paper was immersed in water for 5 minutes and transferred to the lid of a Petri dish containing 3% water agar, with the back of the leaf facing the agar (Mateus et al. 1987).

Ascospores were allowed to discharge for one hour and were examined under a compound light microscope to localize them (Du Pont 1982). Their positions were marked on the medium and each ascospore was transferred to a Petri dish containing PDA (potato, dextrose and agar at 39 g/L of water). Monospore cultures were incubated in total darkness at 25°C in an incubator (DIES model D 39) for 20 days, to obtain mycelium. It was then transferred to a test tube containing 1 ml of sterile distilled water and shaken for 1 minute to break it up. Next, 0.5 ml of the suspension was spread uniformly over Petri dishes containing V-8 medium (100 ml V-8 vegetable juice, 0.2 g CaCO₃, 20 g agar/L of water and pH 6) (Mourichon et al. 1987, Beveraggi et al. 1992). The cultures were incubated at 20°C under continuous light for 2 weeks to stimulate conidial production of both fungi (Romero and Sutton 1997).

After both fungi were identified, conidial suspensions were prepared for use as inoculum. Five ml of sterile distilled water was added to the Petri dishes containing V-8 agar. The agar surface was brushed to release the conidia and the suspension filtered through gauze. Tween 80 (0.02%) and gelatine (Royal) (1%) were added to the filtered suspension to improve distribution and adhesion of conidia to the leaf surface. The concentration of the conidial suspension was determined as the average of two readings made with a haemocytometer (Nikon) and adjusted to 5 x 10⁵ conidia/ml of water (Jacome and Schuh 1993).

Inoculation took place 2 months after planting, when the young plants had 3 to 4 developed leaves (Mourichon et al. 1987), and on the lower surface of the youngest opened leaf. A DeVilbiss No. 15 atomizer operating at a constant pressure of 2 kg/cm² provided a uniform layer of small drops on the leaf surface. Spraying was at a distance of
20-25 cm from the leaf (Jacome and Schuh 1993). After inoculation, the young plants were completely enclosed in transparent plastic bags 70 cm x 50 cm for 48 hours, simulating a humid chamber, which favours conidial germination and establishment of the fungi (Jacome and Schuh 1993, Orjeda 1998).

Three days after inoculation, the following variables were measured at weekly intervals: incubation period, that is the number of days from inoculation until the appearance of the first symptoms; symptom evolution period, that is the number of days from the appearance of first symptoms until the presence of a spot with a necrotic centre; disease development period, that is the number of days between inoculation and the appearance of mature necrotic spots on the leaf, and development rate (r) of the leaf spot diseases as determined by the equation:

\[ r = \frac{1}{t_1 - t_0} \left( \log_e \frac{X_1}{1 - X_1} - \log_e \frac{X_0}{1 - X_0} \right) \]

where: \( t_1 \) = final time, \( t_0 \) = initial time, \( X_1 \) = final severity and \( X_0 \) = initial severity (Castaño-Zapata 2002).

Plants derived from in vitro plantlets of the hybrids ‘FHIA-01’, ‘FHIA-17’ and ‘FHIA-21’ were evaluated under field conditions at the University of Caldas Montelindo farm. It is situated in the municipality of Palestina, in the region of Santángueda, at an altitude of 1050 masl, an average temperature of 24°C, an annual precipitation of 2200 mm and a relative humidity of 86%. ‘Dominico hartón’ and ‘Gros Michel’ were used as susceptible controls. ‘FHIA-01’, ‘FHIA-17’, ‘FHIA-21’ and ‘Gros Michel’ were planted in plots containing 25 plants (5 x 5) randomly distributed and at a distance of 2 m x 3 m of each other. ‘Dominico hartón’ was planted around the plots at equal distance. After the third month, weekly evaluations were done to note the number of functional leaves at flowering and at harvest, and the infection index (II) according to the following equation:

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

where \( n \) = the number of leaves in each grade, \( b \) = the grade, \( N \) = the number of grades used in the scale (7) and \( T \) = the total number of leaves scored (Guzmán and Romero 1996, Orjeda 1998).

The populations of Pseudocercospora musae and Paracercospora fijiensis were determined according to the method developed by Aguirre et al. (1998). The evaluations were conducted on 5 plants of each genotype every 15 days, from the third month following plantation to the harvest. Bunch weight was also noted.

The effect of environmental conditions (maximum, minimum and average temperature, relative humidity and precipitation) on the development of the fungi was analysed.

Results and discussion

The results show that the incubation period of M. fijiensis was 18 days with ‘FHIA-01’ and 15.3 days with ‘FHIA-17’, much longer than in the control ‘Gros Michel’ (Table 1). The results were similar with M. musicola. The symptom evolution and disease development periods in ‘FHIA-01’ and ‘FHIA-17’ were over 55 days, twice as long as in ‘Gros Michel’.

The incubation periods of both fungi were over 15 days in ‘FHIA-21’, much longer than in ‘Dominico hartón’ (Table 1). The symptom evolution and disease development periods were shorter with M. musicola than with M. fijiensis, but in both cases much longer than for ‘Dominico hartón’.

Comparing the disease development rates of both diseases in the hybrids with those in the control confirms that ‘FHIA-01’ and ‘FHIA-17’ are resistant to both fungi (Table 1).

‘FHIA-01’, ‘FHIA-17’ and ‘FHIA-21’ showed significant differences in the number of functional leaves at flowering and harvest in comparison with ‘Gros Michel’ and ‘Dominico hartón’ (Table 2). At harvest, the latter materials had no functional leaves and this was associated with low bunch weight.

At harvest, ‘FHIA-01’ and ‘FHIA-17’ had 5 functional leaves, resulting in higher bunch weights (Table 2), and hence substantiating the positive relationship between the number of functional leaves and bunch weight.

‘FHIA-21’ did not express its genetic potential because of problems with non-fungal disease. Guzmán and Castaño-Zapata (2001) demonstrated ‘FHIA-21’ to be highly susceptible to nematodes. Similarly, Merchán (1996) reported ‘FHIA-21’ was susceptible to the banana streak virus, BSV.

During the vegetative, flowering and harvest phases, ‘FHIA-01’ and ‘FHIA-17’ had relatively similar infection indices, whereas
'Gros Michel' had an infection index of 90 at harvest (Table 2).

In comparison with 'Dominico hartón', 'FHIA-21' had a lower infection index during the vegetative and flowering phases. By harvest, the infection index for 'FHIA-21' had risen to 58 in comparison with 100 for the control. Nevertheless, the bunch weights did not differ significantly (Table 2).

Conidial populations of Paracercospora fijiensis were low (Table 2), confirming the resistance of 'FHIA-01' and 'FHIA-17' to black leaf streak disease. In contrast, 'Gros Michel' had high conidial populations of black leaf streak disease. 'FHIA-21' had smaller populations of conidial populations of black leaf streak disease in comparison with 'Dominico hartón'. The high populations of conidial populations of black leaf streak disease were low (Table 2), confirming the resistance of 'FHIA-01' and 'FHIA-17' to black leaf streak disease. 'FHIA-21' had smaller populations of conidial populations of black leaf streak disease to be more aggressive than Sigatoka disease at the experimental site (Table 2).

Climatic factors were correlated with the development rate of both diseases (correlation coefficient between infection index, temperature and rainfall was $r = 0.68**$ and $r = 0.81**$, respectively). When minimum temperature and weekly cumulative rainfall increased, disease severity also increased and vice versa.

References

Aguirre M., J. Castaño-Zapata, J.A. Valencia, L.E. Zuluaga & C. Arce. 1998 Interacción de Mycosphaerella fijiensis and Mycosphaerella musicola, symptom evolution period (EP) and disease development period (DDP) in FHIA hybrids and their controls. (Mean of 5 replicates and 5 plants)

![Table 1: Incubation period (IP) of Mycosphaerella fijiensis and Mycosphaerella musicola, symptom evolution period (EP) and disease development period (DDP) in FHIA hybrids and their controls. (Mean of 5 replicates and 5 plants)](image)

Means followed by different letters are significantly different according to Tukey's multiple comparison test at 5% probability

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Table 2: Number of functional leaves at flowering (NFLF) and at harvest (NFLH), infection index during the vegetative (V), flowering (F) and harvest (H) phases, population of conidia, and bunch weight (BW) of FHIA hybrids and their controls under field conditions. (Mean of 5 replicates and 5 plants)

<table>
<thead>
<tr>
<th>NFLF</th>
<th>NFLH</th>
<th>V</th>
<th>F</th>
<th>H</th>
<th>IP</th>
<th>EP</th>
<th>DDP</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-01</td>
<td>11b</td>
<td>5 a</td>
<td>33 c</td>
<td>32 c</td>
<td>41 c</td>
<td>11 b</td>
<td>29 b</td>
<td>36.3 a</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>15 a</td>
<td>5 a</td>
<td>38 b</td>
<td>37 b</td>
<td>48 b</td>
<td>15.5 a</td>
<td>25.6 b</td>
<td>35.3 b</td>
</tr>
<tr>
<td>Gros Michel</td>
<td>8 c</td>
<td>0 b</td>
<td>46 a</td>
<td>44 a</td>
<td>90 a</td>
<td>85 a</td>
<td>45 a</td>
<td>15.6 c</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>9 a</td>
<td>3 a</td>
<td>41 b</td>
<td>38 b</td>
<td>58 b</td>
<td>29 b</td>
<td>24 b</td>
<td>18.2 a</td>
</tr>
<tr>
<td>Dominico hartón</td>
<td>7 b</td>
<td>0 b</td>
<td>52 a</td>
<td>43 a</td>
<td>100 a</td>
<td>72 a</td>
<td>30 a</td>
<td>16.9 a</td>
</tr>
</tbody>
</table>

Means followed by different letters are significantly different according to Tukey's multiple comparison test at 5% probability.
The effect of meta-topolin on plantain propagation using a temporary immersion bioreactor


C

ommercial mass propagation is usually limited to value added crops because of the costs associated with labour-intensive conventional in vitro techniques. Progress in automation has been made with the development of temporary immersion bioreactors but the costs need to be reduced and the survival rate of high quality plantlets increased before the technology is widely adopted.

Temporary immersion has been shown to stimulate shoot multiplication. For example, Lorenzo et al. (1998) obtained a 6-fold increase with Saccharum spp. while Escalona et al. (1999) observed a 300% and 400% increase in the multiplication rate of Ananas comosus shoot tip cultures compared to the rates obtained with liquid and solid media.

The cytokinin N6-benzyladenine (BA), also known as BAP, is often used in micropropagation systems. However, in temporary immersion systems it has not increased the multiplication rate of plantain as much as with other crops. A constituent of plant tissues, N6-(3-hydroxy benzyl) adenine, known as meta-topolin, has been used in different crops to induce axillary bud proliferation (Holub et al. 1998) but there are no reports of its use in Musa tissue culture. In this study, the effect of the two cytokinins on the multiplication rate of the plantain cultivar ‘CEMSA 3⁄4’ cultured in a temporary immersion system is compared.

Materials and methods

The temporary immersion bioreactors had a volume of 250 ml. Their description is given in Escalona et al. (1999). Plantain shoots of the cultivar CEMSA (AAB) that had been through three subculture cycles on semi-solid MS medium (Murashige and Skoog 1962) supplemented with 4.44 µmol/L BA were used as starting material.

The leaves and roots were removed from 5 shoots that were cut longitudinally to break apical dominance, for a total of 10 explants per bioreactor. The culture medium (20 ml/explant) consisted of MS salts and vitamins (Murashige and Skoog 1962), supplemented with 3% sucrose and various concentrations of BA and meta-topolin. The concentrations tested were 1.33, 2.22, 4.44, 13.3 and 22.2 µmol/L. Three bioreactors were inoculated for each treatment and each treatment was repeated twice for a total number of 60 explants inoculated for each treatment.

The pH was adjusted to 5.8 before autoclaving at 121 °C and 1.2 kg/cm² for 30 minutes. Shoots were immersed for 4 minutes every 3 hours. Cultures were incubated at 25 °C under cool white fluorescent tubes (30-40 µ mol m² s⁻¹) with a 16-hour photoperiod. After 28 days of culture, all the shoots and buds on the explants were counted and divided by the initial number of shoots inoculated (5) to obtain the multiplication rate. Shoot height and the number of roots per shoot were also determined. A multifactor ANOVA was performed, followed by a least significant difference (LSD) comparison test. Unless indicated otherwise, data are presented as mean.

Results and discussion

A two-way factorial analysis of variance on the type of cytokinins and the concentration shows that the use of meta-topolin resulted in significantly higher multiplication rates. The optimal concentration for multiplication was 4.44 µmol/L (Figure 1). The multiplication rate was significantly lower at the highest
concentration of BA compared to the same concentration of meta-topolin. High concentrations of meta-topolin do not seem to inhibit multiplication rate.

Results on shoot height after 28 days of culture are showed in Figure 2. Shoots did not become any longer after this phase. Concentrations of 13.3 and 22.2 µmol/L of BA and meta-topolin significantly decreased shoot height. The lowest concentration of meta-topolin (1.33 µmol/L) resulted in significantly longer shoots and a higher number of roots per shoot.

The results presented in this paper agree with the observations of Werbrouck et al. (1996) and Strnad et al. (1997), namely that meta-topolin is more active than BA in the promotion of shoot formation.

Although cytokinins generally inhibit root development, our results show that using low concentrations of meta-topolin and BA did not inhibit the number of roots per shoot (Figure 3). An increased root/shoot ratio has been observed in in vitro potatoes plantlets in culture medium with a low concentration of meta-topolin (Baroja-Fernández et al. 2002). The authors observed the initiation of lateral roots after addition of this cytokinin. The absence of effect on in vitro root growth has also been observed by Werbrouck et al. (1996) on Spathiphyllum floribundum, indicating a potential commercial treatment for improving the establishment of transplanted plantlets.

According to some authors, the stimulating effect of meta-topolin on plantlet growth is only observed at very low concentrations. Plantlets grown at a high concentration (0.5 mg/L) develop a basal callus and do not root (Baroja-Fernández et al. 2002). In our experiments, the highest concentration of meta-topolin inhibited root formation but no callus was observed at the shoot base.

Plantain shoots ready for acclimatization should have the following characteristics: they should be longer than 2.5 cm, have more than three leaves and a girth of more than 0.5 cm. Shoots treated with meta-topolin at concentrations of 1.33 to 4.44 µmol/L met these indicators and as a result they don not have to undergo an elongation phase in the bioreactor before acclimatization (Figure 4).

Experiments on the effect of meta-topolin during the acclimatization phase and on somaclonal variation and the performance of the plants in the field are being conducted at the National Corporation of Bananas in Costa Rica (CORBANA).
Biology and integrated pest management for the banana weevil

The banana weevil *Cosmopolites sordidus* (Germar) is the most important insect pest of bananas and plantains (*Musa* spp.). The larvae bore in the corm, reducing nutrient uptake and weakening the stability of the plant. Attack in newly planted banana stands can lead to crop failure. In established fields, weevil damage can result in reduced bunch weights, mat die-out and shortened stand life. Damage and yield losses tend to increase with time.

A paper, “Biology and integrated pest management for the banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae)”, written by Clifford S. Gold of the International Institute of Tropical Agriculture (IITA), Jorge E. Pena of the University of Florida and Eldad B. Karamura of the INIBAP regional office in Uganda, and published in *Integrated Pest Management Reviews* (6:79-155, 2001), reviews the research on the taxonomy, distribution, biology, pest status, sampling methods and integrated pest management (IPM) of banana weevil. Salient features of the weevil’s biology include nocturnal activity, long life span, limited mobility, low fecundity and slow population growth. The adults are free living and most often associated with banana mats and cut residues. They are attracted to their hosts by volatiles, especially following damage to the plant corm. Males produce an aggregation pheromone that is attractive to both sexes. Eggs are laid in the corm or lower pseudostem. The immature stages are all passed within the host plant, mostly in the corm. The weevil’s biology creates sampling problems and makes its control difficult. Most commonly, weevils are monitored by trapping adults, mark and recapture methods and damage assessment to harvested or dead plants.

Weevil pest status and control options reflect the type of banana being grown...
and the production system. Plantains and highland bananas are more susceptible to the weevil than dessert or brewing bananas. Banana production systems range from kitchen gardens and small, low-input stands to large-scale export plantations. IPM options for banana weevils include habitat management (cultural controls), biological control, host plant resistance, botanicals and (in some cases) chemical control. Cultural controls have been widely recommended but data demonstrating their efficacy are limited. The most important are clean planting material in new stands, crop sanitation (especially destruction of residues), agronomic methods to improve plant vigour and tolerance to weevil attack and, possibly, trapping. Tissue culture plantlets, where available, assures the farmer with weevil free material. Suckers may be cleaned by paring, hot water treatment and/or the applications of entomopathogens, neem or pesticides. None of these methods assure elimination of weevils. Adult weevils may also invade from nearby plantations. As a result, the benefits of clean planting material may be limited to a few crop cycles. Field surveys suggest that reduced weevil populations may be associated with high levels of crop sanitation, yet definitive studies on residue management and weevil pest status are wanting. Trapping of adult weevils with pseudostem or corm traps can reduce weevil populations, but material and labour requirements may be beyond the resources of many farmers. The use of enhanced trapping with pheromones and kairomones is currently under study. A combination of clean planting material, sanitation and trapping is likely to provide at least partial control of banana weevil. Classical biological control of banana weevil, using natural enemies from Asia, has so far been unsuccessful. Most known arthropod natural enemies are opportunistic, generalist predators with limited efficacy. Myrmicine ants have been reported to help control the weevil in Cuba, but their effects elsewhere are unknown. Microbial control, using entomopathogenic fungi and nematodes tend to be more promising. Effective strains of microbial agents are known but economic mass production and delivery systems need further development. Host plant resistance offers another promising avenue of control. Numerous resistant clones are known, including ‘Yangambi km 5’, ‘Calcutta 4’ and ‘Pisang awak’. Resistance is most often through antibiosis resulting in egg or larval failure. Banana breeding is a slow and difficult process. Current research is exploring genetic improvement through biotechnology techniques including the introduction of foreign genes. Neem has also shown potential for control of banana weevil. Studies on the use of other botanicals against banana weevil have failed to produce positive results. Chemical control of banana weevil remains a common and effective method for larger scale producers but is beyond the reach of resource-poor farmers. However, the weevil has displayed the ability to develop resistance against a broad range of chemicals.

In summary, cultural control remains the most available approach for resource-poor farmers. A combination of several cultural methods is likely to reduce weevil pressure. Among the methods currently under study, microbial control, host plant resistance and neem appear to offer the most promise.

Impact of improved banana varieties on livelihoods in East Africa

In contrast to other major staple crops, the vast majority of banana varieties grown worldwide are the result of farmers’ selections rather than breeding programmes. In the past two decades, for the first time, new improved varieties have been made available to farmers to grow in their fields. Again contrasting with other major crops, on a worldwide scale, it is smallholder farmers who are adopting the new varieties as opposed to the farmers growing bananas for the international market. In East Africa improved varieties have reached smallholders through national agricultural research systems (NARS) or through NGOs or development projects. For instance the
The Kagera Community Development Project (KCDP) has estimated that 2,500,000 banana suckers have been diffused as the result of a KCDP-managed project to distribute improved varieties in Kagera District, Tanzania (KCDP 2003).

By evaluating and predicting the effects of improved varieties, organizations can target their work more effectively towards enhancing livelihoods and, ultimately, alleviating poverty. However, studying impact with such objectives presents some interesting challenges. Banana, being a mainly subsistence crop, cannot be studied by examining changes in marketed volumes and prices alone. For a perennial typically grown along with other annual crops and managed as one of multiple food-producing and income-earning activities, the effects of adoption on overall household income are not easy to trace. Useful for diverse purposes and often managed by a number of household members, the contribution of bananas to family welfare is complex.

Furthermore, a realization of the limitations of previous studies of impact of crop technologies has incited some changes in the ways impact assessments are implemented. Researchers of impact are asking themselves questions such as: Who will learn from the results of this impact assessment and how? Are we asking the right questions using the right methodologies to understand how poverty is affected? How can we ensure the participation of all the people who should be involved? Under what policy and institutional conditions will the positive impacts of improved bananas be sustained over time?

**A new approach**

A team composed of national partners in Uganda: the National Agricultural Research Organization (NARO) and Makerere University, and in Tanzania: the Agricultural Research and Development Institute (ARDI), and Sokoine University, together with international partners, the International Food Policy Research Institute, INIBAP and the International Institute of Tropical Agriculture (IITA) are conducting a four-year project to assess the impact of improved varieties on livelihoods in Uganda and Tanzania. To date, the project has received support from the United States Agency for International Development (USAID), The Rockefeller Foundation and the International Fund for Agricultural Development (IFAD).

The project paves the way in its adoption of a combination of approaches that makes it quite unique, including the:

- incorporation of results into a process of institutional learning and change (ILAC) for the national and international partners and others elsewhere;
- integration of the assessment of sociological, economical and biological factors;
- building of capacity in-country to assess impact and particularly to develop capacity in the field of sociology as it relates to agriculture;
- answering of questions about poverty through a Sustainable Livelihoods (SL) Approach (for more information on SL see http://www.livelihoods.org).

The project aims to provide banana researchers and extension services with comprehensive information to use in setting research priorities, selecting “best-bet” traits and genetic backgrounds for traits, timing research efforts, identifying and targeting farmers who are set to benefit most, and designing appropriate mechanisms for dissemination of improved bananas.

To achieve these aims, the study is combining in-depth economic and sociological research using a sample survey of 800 households, with focus group interviews at a community level and the projection of national and regional impacts with IFPRI’s Dynamic Research Evaluation for Management (DREAM) model and other economy-wide models (more information is available on the web at http://www.ifpri.org/themes/grp01/dream/dream.htm). In addition, from the project’s outset, the institutes involved have been gradually preparing the ground for the internalization of the results. In other words, this particular impact assessment will not end up on the shelf, but will provide a basis from which research and development efforts might be improved and better tuned towards addressing poverty.

**Work in progress**

Although some of the economic research was initiated earlier, the project began in earnest in 2002, when a planning workshop took place in Kampala, Uganda. Researchers from sociological, economics...
and agricultural disciplines were brought together to plan the implementation of the project, using the Sustainable Livelihoods Framework to develop the research tools and questions (see below). Also at this occasion, the idea was aired to form a steering committee composed of senior management level staff from the participating institutions who would provide guidance for the project and act as conduit by which the results would be used to improve future banana improvement and dissemination efforts. The steering committee was formed and had its first meeting in Kampala in October 2003, where it reviewed the research process and progress to date, and made initial plans for communicating about the project back to the participating institutions.

Key research questions

Which are the most appropriate dissemination pathways (organization and form, or extension or delivery systems) for technologies?

Dissemination pathways may be characterized according to the involvement of the government, private sector and NGOs, as well as organized farmer groups and spontaneous farmer-to-farmer dissemination. Other factors held constant, pathways can be compared according to the relative effectiveness of germplasm diffusion and the groups that they reach. Pathways are also likely to differ in terms of how the benefits from the adoption of new germplasm are distributed among community members.

In the Ugandan context, recent reforms to decentralize extension services and make them accountable to communities are likely to affect the dissemination pathways. Which farmers are most likely to adopt, and which economic, sociological and policy factors constrain their decision?

Farm households vary in social, natural and economic endowments and also in their perceptions of the world around them, including varieties of banana and their attributes. The context within which farmers make a decision colours the outcome. A large part of the study is focused on farm households, the characteristics of their economic, social and natural resources and the positive and negative perceptions of the household decision-makers to the attributes of different banana varieties, and to their vulnerability to pests and diseases.

Econometric models are being used to identify the factors that are likely to significantly affect farmers' adoption of specific banana types defined in accordance with taxonomic descriptors, and to profile the farmers and communities most likely to adopt. Taxonomic specificity in the data collection enables modellers to predict the adoption of planned technologies, such as transgenic varieties resistant to black leaf streak disease, and analyse the trade-offs with other traits. Sociological approaches are investigating in detail the links between health, labour input and the development of skills and knowledge associated with the adoption of new varieties and associated technologies. The effects of social networks and the involvement of household members in community institutions on adoption of varieties and other management practices is also under study.

What is the probable impact of technologies on the livelihoods of smallholder farmers?

The SL Framework encourages the widening of concepts of poverty – to take account of changes in assets but also changes in vulnerability to and the processes that influence poverty. While the econometric approach enables the prediction of the impact of adoption in terms of relatively static farm size, income and wealth categories, the livelihoods approach enriches the understanding of these categories and how they change over time. Other types of livelihood outcomes, including reinvestment in social, financial, human, or natural assets or reduction in vulnerability may also be considered through the livelihoods approach. Outcomes are considered separately for socially differentiated groups, including households with different poverty/wealth status, as well as for men and women separately within households. For example, if a certain variety has benefits for brewing, does that provide additional income for men or women depending on the type of household and how does this affect the contribution of banana to the wellbeing of the household?

What is the expected economic impact of technologies at the national level in different policy scenarios, and how do the distributions of the net benefits among social groups compare?

The sub-national and national level analysis will be performed using DREAM, IFPRI's ex ante economic surplus model, for assessing the benefits of technology and policy interventions. The data elements of the analysis were defined by a roundtable
of stakeholders and scientists, and basic market data has already been compiled by IFPRI for banana in Uganda.

Findings can be presented in several ways, including by stratification domains characterized by gender, banana production system, population density and market access. As detailed results become available from the farm-level analysis, the adoption and technology assumptions of the initial simulations will be updated, and new analyses carried out.

The results will serve as an input into the priority setting process for technologies defined by crop and trait. Scenarios depicting technologies within trade and policy environments are simulated interactively to highlight “best bets”. Addressing these criteria typically requires the calculation of: rate of return to research investment, size of social and private benefits relative to risks, benefit shares earned by consumers, commercial and smallholder producers, or efficiency and equity trade-offs. Estimated effects on the banana industry can then be traced through other sectors of the economy, nationally and regionally, with other economy-wide models.

*How can the evaluation of impacts using innovative approaches increase the capacity amongst the participating institutions to focus their work on poverty alleviation?*

This key question investigates how the process of evaluation, conducted in a participatory manner using a multi-disciplinary approach can lead to improved performance of the organizations involved. Institutional learning and change (ILAC) has been defined as “the process of reflection and re-framing of knowledge that results in changed behaviour and improved performance” (Blackshaw 2003). The application of ILAC in a practical sense requires a further definition of the specific performance improvements sought and an identification of the organizations involved.

In this study, performance improvement is sought in the area of targeting banana research towards poverty alleviation. The SL framework provides a theoretical model of the different dimensions thought to contribute to poverty and its alleviation. An ILAC approach built into the research design will help ensure that findings from the research are used by the participating organizations in future priority-setting and planning exercises for banana research and development. The overall strategy for ILAC includes (based on Patton 1996):

- training for the research team on the SL approach and interdisciplinary methodologies and approaches,
- awareness raising for staff and managers in participating organizations and incorporation of their ideas into the project design,
- action learning, whereby banana improvement researchers and their organizations are actively engaged in the evaluation process,
- interdisciplinary planning and development of findings,
- workshop of participating organizations and policy makers to discuss implications, draw conclusions and most importantly, agree upon an action plan for banana research and development based upon the findings from the study,
- briefing papers used to communicate with a broader audience in participating countries.

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**Individual projects being undertaken by students in the impact assessment of improved banana on livelihoods in East Africa**

- Fredrick Bagamba. Market access and banana production in Uganda.
- Mgenzi Byabachwezi Said. Farmers’ perception of pests and diseases towards adoption of improved banana cultivars in Kagera Region, Tanzania.
- Svetlana Edmeades. Variety attributes and attribute trade-offs within the framework of household production models.
- Jackson Nkuba. Assessing the impacts of improved banana cultivars on livelihoods of banana farmers in Kagera Region, Tanzania.
- Enid Katungi. Social capital and technology adoption on small farms: A case of improved banana management technology in Uganda.
- Anthony Begumisa. Impact of malaria on labour in the production of improved bananas.
- Musimbi Jimmy. A case study in central Uganda investigating gender and the adoption of improved banana cultivars.
- Xavier Nsabagasani. Banana production technology and farmers livelihoods.
In 2003 the research team was brought together. Under the supervision of INIBAP and IFPRI scientists, a total of six doctorate students and four students working towards MA degrees are taking part in the project – only one of them is not native to East Africa (see box). The fieldwork is well under way and integration between the different disciplines is already reaping benefits through meetings and workshops that have established a better understanding of each other’s vocabulary and a common research framework that rationalizes the research from the different disciplines.

A data sharing agreement was established between all partners to allow the shared use of the data being collected while protecting the individual student’s rights to publish theses and scientific papers. Activities to increase the awareness of the aims of the project within the partner institutes and the farming community are being planned. During the next two years the results of the different studies will gradually become available and an integrated analysis will be presented to the project stakeholders. From there the focus will turn to the steering committee and partner institutes to assimilate from this analysis the key lessons to be taken up and used to bring about positive changes to make future banana research more effective.

References


Jean Champion (1922 - 2003)

One of the key figures of banana research, Jean Champion passed away on 3 September at the age of 81. Since the fifties he had devoted his career to this plant and its cultivation. For him it was a case of true commitment and immense passion. All those who have worked on banana, whatever their scientific discipline or their approach to its problems, will remember his inestimable work.

Jean Champion was born in Nancy on 21 June 1922. After studying agronomy at the Nancy Agronomic Institute, he was among the researchers who undertook a specialized training at ORSTOM to strengthen their knowledge of taxonomy and genetics. This earned him a place at the prestigious Ecole Normale Supérieure where the courses in cytogenetics where held. There, he developed skills in agronomy, taxonomy and genetics, which he later put to the service of the plant he loved so much, the banana.

He then joined the Guinea team, a research group that left its mark on the history of Cirad. From 1948 to 1958, he was scientist in charge of the agronomy team and devoted most of his energies to the banana. In addition to Guinea, his work took him to Côte d’Ivoire, Cameroon, Guadeloupe and Martinique.

Returning to France, he became Head of the banana pro-gramme for more than twenty-five years. We recall his field visits during which he would generously provide advice and criticism that were always appropriate and full of good sense.
His many publications bear witness to the breadth of his work. Two in particular epitomize his career and undeniably represent a valuable legacy, in that even today they still constitute valuable references for many research workers. One is “Le bananier”, published in 1963, and the other is “Les bananiers et leur culture, botanique et génétique” which is a seminal work in the world of banana taxonomy.

A tireless worker, Jean Champion inspired many people to pursue careers in banana research. For many of us, he was a real leader, not only in as a scientist, but also as a person with strong views on international cooperation relationships with partners. He was among those who launched regional cooperation programmes in the Caribbean, Latin America and Africa.

He was also part of the group of experts who, in December 1983, at the request of the International development research centre of Canada, brought INIBAP to the baptismal font. He was a member of the founding Board of Trustees of this international network. Even after his retirement in 1984, he remained active and continued to infect us with his enthusiasm.

By his work, his expertise and his vision, Jean Champion left his mark on the history of the banana, especially in West and Central Africa and in the French West Indies. All those who knew Jean Champion will remember his professional and human qualities, tinged with great rigour, much modesty and generosity. Apart from the scientific legacy he has bequeathed us, he also leaves the memory of a great humanist.

Jacky Ganry

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**Effect of crop sanitation on banana weevil**

*Cosmopolites sordidus* (Germar) populations and associated damage

*Michael Masanza*

PhD thesis submitted to Wageningen University, Wageningen, The Netherlands, September 2003

Banana is an important food security crop in the East African Great Lakes region, but banana weevil (*Cosmopolites sordidus*) is a major constraint in its production. A review of the available control options showed that no single strategy has been effective in the control of the pest (Chapter 1). Cultural control strategies such as crop sanitation form the first line of defence against the pest and are the most readily available strategies to resource-poor banana farmers in East Africa. In this thesis, we report the effect of crop sanitation on *C. sordidus* population and damage in farmers’ fields. Laboratory and field studies were conducted on the biology and ecology of *C. sordidus*. This provides insights into the mechanisms by which crop residues can be manipulated to control the pest.

Choice experiments were conducted in the laboratory in Uganda at Kawanda Agricultural Research Institute to determine attraction and acceptance of different aged crop residues to *C. sordidus* (Chapter 2). In the first experiment, studies focused on different types and ages of residues of one susceptible highland banana clone ‘Nabusa’ (genome group AAA-EA). Corms attracted 65% of the test weevils, pseudostems 30%, and 5% were non-respondents. Females laid a higher number of eggs on young than old corms. In the second experiment, the same parameters were measured on banana residues of selected clones based on their levels of resistance and tolerance to banana weevil damage. Corms were more attractive to adults than pseudostems and flower stalks except for fresh residues of resistant clones. Pseudostems were more attractive than flower stalks with a few exceptions. The number of eggs per female did not differ across clones, but varied with residue age. The number of eggs per female was highest on flower stalks, followed by corms.
and pseudostems. On flower stalks, it was highest on old ones. In Chapter 3, we report the results of on-station and on-farm trials, conducted in Uganda to investigate the effect of crop residue management on attack, oviposition and distribution of the C. sordidus on crop residues and growing plants. Oviposition and distribution were assessed on different aged standing and prostrate residues by destructive sampling. Similar data were collected from banana fields maintained at three sanitation levels. In the first experiment, oviposition occurred on residues as old as 120 days, but mainly between 0-30 days post-harvest. Weevil infestation varied among banana clones. In the second experiment, oviposition levels on standing residues were not significantly affected by age. Oviposition levels on prostrate four-week-old residues were two times higher than those on two-week-old residues, while the number of larvae on eight-week-old residues was three times higher than on two-week-old residues. The number of pupae did not differ at all ages of prostrate and standing residues. The number of adults in standing and prostrate residues on 16-week-old residues was two times higher than that on two-week-old residues. In the third experiment, farmers' fields maintained at high sanitation level had 50% lower eggs per residue than those kept at low sanitation level. The number of immatures per residue was 50% higher on banana corms than on pseudostems. Larvae were three times more abundant at low than at high sanitation. The number of pupae per residue at low sanitation was six times higher than at high sanitation level. Residues in fields at high sanitation hosted 50% less adults per residue than in fields at low sanitation. The results suggest that removal and splitting of corms after harvest is effective and practical in destroying immature growth stages of the pest. The question arises if C. sordidus completes its life cycle in crop residues. We conducted laboratory trials to investigate C. sordidus eclosion success and larval survivorship on different aged banana residues at Kawanda in Uganda (Chapter 4). When we inserted less than 24-hour-old larvae into corm pieces of four different aged susceptible banana cultivar 'Kisansa' (genome group AAA-EA), eclosion rates were 66% in fresh, 67% in moderately old, 64% in old, and 58% in very old residues. To assess immature survival, less than 24-hour old larvae were put on banana corms of suckers and crop residues of the same cultivar 'Kisansa' in single rearing chambers. The number of surviving individuals was recorded at three-day intervals until adults emerged. The proportion of surviving individuals 48 days after eclosion was 12% on sword suckers, 10% on maiden suckers, and 7% on flowered plants; after 51 days it was 12% on fresh, 8% on old, and 5% on very old corms. Larval development time and mean date of adult emergence increased with plant and crop residue age. Crop residue age did not affect adult weight, but the females were heavier than males. These results imply that fresh residues offer better nutrition for C. sordidus than old residues. One of the cultural practices in controlling C. sordidus is the covering of banana stumps with soil after harvest. The effect of this practice on C. sordidus oviposition levels was investigated at Sendusu, Kawanda Agricultural Research Institute (KARI) and in the Ntungamo district of south-western Uganda (Chapter 5). In the first experiment we assessed oviposition levels in a banana system comprising growing plants and residues. Oviposition increased from sword suckers, reaching a peak 1 to 7 days after harvest, and it decreased thereafter. In the second experiment conducted on farmers' fields, corms received 70% of the eggs and pseudostems 30%. The area 5-10 cm below the collar received 27% of the eggs, the area 0-5 cm above the collar 30%, and the area 5-10 cm above the collar 0.3%. The remaining eggs (43%) were laid 0-5 cm below the collar. The effect of stump height and covering the stumps was evaluated in both the wet and dry seasons at Kawanda near Kampala and Ntungamo in the southwest of the country. Cutting stumps to ground level alone had no effect on oviposition. Covering post-harvest banana stumps reduced banana weevil oviposition in the wet but not in the dry season. Apart from covering banana stumps, it is often recommended that post-harvest corms and pseudostems be removed to reduce weevil populations and damage. An on-farm study of the effect of crop sanitation on C. sordidus populations and corm damage was conducted in the Ntungamo district of south-western Uganda (Chapter 6). Farmers practiced sanitation levels that can be broadly defined as low, moderate and high. Soil conservation methods such as making
bunds, mulching and application of manure were treated as covariates. Increase in sanitation level from low to high significantly reduced adult weevil population density from 52 000 to 13 000 ha$^{-1}$, lowered corm damage by 41% after three years, enhanced plant girth by 10% and plant height by 13% at flowering and increased yield by about 70%. There was a weak relationship between $C. sordidus$ population density and plant damage. Shifting from a low to a high sanitation level significantly reduced corm damage. This study has demonstrated the great potential of crop sanitation in controlling $C. sordidus$ populations, and reducing damage to the crop.

The on-farm study was complicated by farmer attrition and changes in management with time. So, we conducted a controlled experiment at Kawanda whose results are reported in Chapter 7. We evaluated the effect of crop residue removal on weevil population, weevil damage, nematode and arthropod natural enemy incidence in isolated young banana stands. A closed banana weevil population assumes no emigration or immigration between plots. We infested isolated banana plots with 5-10 weevils and a complex of 3000 nematodes per plant. As harvesting started, we subjected the plots to low, moderate and high crop sanitation levels. High sanitation levels reduced trap catch by up to 40%, and weevil population by up to 43%. However, weevil attack increased on standing plants causing up to 34% yield reduction. Crop sanitation seemed to reduce nematode populations but not damage. Plant growth was not affected until the fourth crop cycle when girth reduced by 10% and height by 6% in plots under high sanitation compared to plants in low sanitation fields. Plant girth and height increased with crop cycle. Complete removal of crop residues resulted in a three-fold reduction in arthropod natural enemies compared to leaving the residues intact, but it did not affect total oviposition on growing plants. In young banana stands with closed weevil populations, removal of crop residues seems to expose growing plants to increased weevil attack.

A summary of our results on biology and ecology of $C. sordidus$ is given (Chapter 8). The place of crop sanitation in an IPM framework with other control strategies is discussed. Conclusions from this thesis can be summarized as follows:

- Banana corms compared to pseudostems and other banana plant parts are more attractive to $C. sordidus$.
- Chopping banana crop residues and spreading them to dry reduces $C. sordidus$ populations and crop damage.
- Crop sanitation, apart from keeping $C. sordidus$ populations in banana fields low, may help in suppressing nematode incidence.
- $Cosmopolites sordidus$ can successfully complete its life cycle in crop residues and as such farmers should endeavour to keep banana fields clean in order to reduce weevil populations.
- The notion that crop sanitation is labour intensive may still hold, but many small-scale farmers in our study area adopted the method and successfully reduced weevil populations and damage, improving the banana yields.
- Full benefits of crop sanitation may be realized if this method is adopted as a community effort.
- Complete removal of all crop residues in young banana stands may expose standing plants to increased attack.
- Crop sanitation does not offer complete control. Therefore it should be combined with other methods that reduce or prevent an increase in weevil numbers, such as biological control and planting resistant cultivars in order to obtain a sustainable control of $C. sordidus$.

Future perspectives

- Since the on-station trial was conducted under conditions of similar weevil pressure, it would be beneficial to carry out such a trial under various levels of weevil pressure, because different weevil pressures may respond differently to crop sanitation.
- Studies on weevil migration among banana farms may be necessary so that farmer communities could be advised on how to better implement crop sanitation practices.
- A cost: benefit analysis study may be helpful in recommending a particular crop sanitation level to small-scale farmers.
- The impact of crop sanitation on a few selected arthropod natural enemies needs to be assessed, in order to find out whether crop sanitation enhances or frustrates biological control using them.
On-farm analysis of nematode infestation and soil fertility as constraints to the productivity of banana-based production systems in Uganda

Mariana Rufino

MSc Thesis in Plant Sciences submitted to Wageningen University, The Netherlands, September 2003

Yield decline for East African highland bananas has been attributed to soil nutrient depletion, pests, diseases and a number of socio-economic factors. Among those factors, nematodes and soil fertility have been identified as critical biophysical constraints to productivity. It is suspected that nematodes negatively affect nutrient uptake by the plant and therefore reduce yield.

The objectives of this study were to examine the relationships between nematode damage to the root system and banana nutritional status under farmers’ field conditions and its implications to crop productivity. Furthermore, it was expected to identify the main constraints to the productivity of the banana-based systems within the biophysical environment.

A survey was carried out in three contrasting regions of Uganda, where yields have shown different trends in last years: Bamunanika and Kisekka located in Central Uganda and Ntungamo located in South-western Uganda. Data on nematode infestation, root damage, crop nutritional status, soil fertility and yield were collected.

*Radopholus similis* was responsible for the root damage at Bamunanika and Kisekka, whereas *Pratylenchus goodeyi* was responsible for the root damage at Ntungamo. Boundary line analysis revealed that the K concentration in the leaves was seriously affected when root damage exceeded 35%. However those levels of damage were not common at any of the sites. The critical K concentrations in the soil were higher for maximum yield than for maximum K concentration in the leaves suggesting that foliar diagnosis is not a very accurate tool to guide fertilisation in cooking bananas.

In the sandy soils of Ntungamo, pH was the main constraint to the productivity of the system together with low nutrient supply and root damage by *P. goodeyi*. Nevertheless, the highest yields were obtained at this site. Apparently, limitations imposed by soil chemical properties and nematode damage are partly offset by the large additions of external organic inputs. Average yield was 21.2 t fresh bananas ha⁻¹.

At Bamunanika, sandy soils with a very high C/N ratio, root damage by *R. similis*, poor management (weed infestation, no use of mulching) and the intensive intercropping with perennials (coffee and shade trees) represented the main constraints to productivity. The yield-reducing factors plus the scant addition of external organic inputs determined that productivity at this site was extremely low. Average yield was 3.2 t fresh bananas ha⁻¹.

Main constraints to the productivity of the bananas at Kisekka were nematode damage and poor management. Yield was on average 13.8 t fresh bananas ha⁻¹. The scope for yield improvement appeared to be much higher at this site because soil fertility was not the most limiting factor.
Spatial distribution and effect of plant-parasitic nematodes on root systems and plant nutritional status of bananas in Uganda

Herbert A. L. Talwana

PhD thesis submitted to Katholieke Universiteit Leuven, Leuven, Belgium, March 2002

Highland bananas account for 75% of production in Africa and about 20% of the world’s banana production. In Uganda, 85% of the bananas grown are East African highland bananas. They are grown between 1000 and 2000 m in altitude. However, banana production in Uganda is declining due to a range of interacting abiotic and biotic factors among which are declining soil fertility and plant-parasitic nematodes. All major banana cultivars are susceptible to nematodes that singly or in association with other factors are major constraints to banana production in all banana-producing regions.

Plant-parasitic nematodes are recognised as a serious pest of East African highland bananas but many questions concerning their role in the decline of the banana production are still unanswered. For example, it is not known where exactly in the root system these nematodes feed, whether the different species feed in different places, whether the damage caused by nematodes depends on place of infection and if the differences in root development observed between Musa genotypes affect nematodes and their feeding. In addition, by suppressing root growth and activity, nematodes may also influence the nutritional status of the plants. Conversely, soil nutritional status would also affect nematode infection and damage, this being severe where mineral nutrients are deficient. Consequently, it could be possible that manipulation of mineral nutrition may be an important tool to manage nematodes and limit the damage caused by nematodes in bananas.

This study was initiated with the general objectives of (i) describing the spatial distribution of populations of Radopholus similis, Pratylenchus goodeyi, Helicotylenchus multicinctus and Meloidogyne spp. and the damage they cause in banana root systems under highland conditions; (ii) quantifying nematode infection and damage on banana root systems and plant growth (iii) verifying the influence of the nematode species on the severity of the damage under highland conditions; and (iv) exploring the relationship between nematode infection, damage and plant nutrition under highland conditions. Results show that nematode populations are randomly distributed along the primary roots while nematode damage is higher close to the corm than further along the primary roots. This effect was independent of cultivar and production area, implying that when assessing genotypes bred for nematode resistance, any section of a primary root can be used for nematode reproduction.

Banana root characteristics play an important role in nematode infection and damage. Number and root size is the critical factor in plant tolerance to nematodes. Plants with more roots and/or vigour are less debilitated by nematodes. However, the pathogenicity on bananas of the nematode species seems far more important in influencing the level of infection and damage. This study also showed that nematode infection in bananas impairs nutrient absorption and distribution in the banana tissues. Supplementation of soil nutrients as a nematode control measure in bananas reduces nematode infection and reproduction but this effect depends on nematode species and nutrient source. The key to avoiding a rapid yield decline of East African highland bananas, therefore, rests with the promotion of vigorous root growth (for example by mulching and applying fertilizers) and/or the elimination of those factors that cause reduced root growth and development, namely, nematodes, high soil temperature and weevils.
Incidence of plant parasitic nematodes on plantain (Musa spp., AAB) in Nigeria and their effect on root health, plant growth and yield

Monisade Omolara Rotimi

PhD thesis submitted to Laboratory of Tropical Crop Improvement, Katholieke Universiteit Leuven, Leuven, November 20, 2003. The research was carried out at IITA Onne, with scientific supervision by the late Paul Speijer, and funded by GTZ (Germany), DGCD (Belgium) and IITA.

Eleven plant parasitic nematode species were associated with plantain in southern Nigeria. Listed in decreasing order of frequency of occurrence, these species were Helicotylenchus multicinctus, Hoplolaimus pararobustus, Pratylenchus coffeae, Radopholus similis, and Meloidogyne spp. (second stage juveniles). Other nematode species include Helicotylenchus dihystera, Pratylenchus zeae, Pratylenchus brachyurus, Rotylenchulus reniformis, Scutellonema and Criconemoides spp. which occurred at less than 5% of the sites. The results suggest that P. coffeae followed by R. similis are the major biotic constraints of plantain production in southern Nigeria. Higher losses are anticipated by these nematodes than by either black leaf streak disease or the banana weevil.

An on-farm multifactorial experiment was established in Obrikom, southeastern Nigeria, to assess the influence of oil palm bunch refuse as mulch on the growth response of plantain (Musa AAB-group cv. ‘Agbagba’) to plant parasitic nematodes. Vegetative growth was improved by mulch. Subsequently, the growth and yield responses of plantain cv. ‘Agbagba’ to plant parasitic nematodes were assessed in the presence or absence of wood chip mulch. The experiment was laid out at the High Rainfall Station of the International Institute of Tropical Agriculture (IITA) in Onne, southeastern Nigeria. Mulch improved plant growth and allowed better sucker production. Mulched plants were harvested 115 days earlier than the nonmulched plants. Nematode damage resulted in 46% yield reduction in mulched plants and 54% in the nonmulched ones. Toppling encountered with the mulched plants was 23% compared with 16% in the nonmulched. The type of management (mulching) adopted determined the predominance of a species in a nematode population mixture.

A pot experiment was carried out at Onne, to assess the differential susceptibility of plantain cultivars ‘Agbagba’ (a False horn) and ‘Obino l’ewai’ (a French) to plant parasitic nematodes at early growth stage. Total number of plant parasitic nematodes was positively correlated with root necrosis on the two cultivars. Additionally, Meloidogyne spp. and H. multicinctus were positively correlated with root galling on cv. ‘Obino l’ewai’, while R. similis was also positively correlated with root galling on cv. ‘Agbagba’. Our results suggest that among plantain cultivars, there is variation in nematode susceptibility and symptom expression. Therefore, effects of plant parasitic nematodes on the growth and yield responses of the two cultivars was compared in a mulched experiment in the field. Nematodes caused 48% yield reduction on cv. ‘Agbagba’ and 51% on cv. ‘Obino l’ewai’. We conclude that nematodes cause on average 50% reduction in yield of plantain in Nigeria and an average of 20% total loss due to toppling of plants carrying immature bunches. In an integrated management concept, mulching is an attractive approach to the management of plant parasitic nematodes on plantain.
Evaluation of virulence of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* on the developmental stages of the banana weevil, *Cosmopolites sordidus*

The banana weevil, *Cosmopolites sordidus* (Germar), is one of the major pests causing damage to the plant. Entomopathogenic nematodes (EPN) belonging to the genera *Steinernema* and *Heterorhabditis* are biological control agents of the weevil and it may be possible to incorporate them into integrated pest management programmes. The objective of this study was to evaluate the virulence of *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* on adults and larvae of the last instar of the banana weevil.

The bioassay comprised infection of individuals on multiple-well plates with filter paper, at concentrations of 10, 100 and 1000 infective juveniles/25µl. The numbers of dead individuals per plate were recorded at 12-hour intervals up to a maximum of 120 hours for larvae and 228 hours for adults. The bodies were transferred to a dry chamber (development of nematode within the insect) and then to a “white” chamber (emergence of infective juveniles). Records were taken of mortality of adults and larvae, multiplication of infective juveniles and duration of emergence.

Under the conditions of evaluation, adults and larvae were both susceptible to attack by infective juveniles by the two EPNs, although they reacted differently to an increase in dose. Symptoms typical of infection and multiplication of infective juveniles of both EPN species were clearly evident in the larvae. Intrinsic conditions such as the limited niche of the insect and the high humidity within the banana corms that favour nematode survival, together with the mortality as recorded at low concentrations of infective juveniles and the capacity for development particularly in larvae, suggest that these EPNs have promise for the control of banana weevils in the field.

Source: Paula A. Sepúlveda C., Alberto Soto G. y Juan C. López N from the University of Caldas, Manizales, Colombia. E-mails: sepulveda_cano@yahoo.es, alberto364@hotmail.com y juancarlos.lopez@cafedecolombia.com

Analysis of pseudostem residues of ‘Valery’ and ‘Grande naine’

In Colombia, in the Uraba Antioqueño and Magdalena zones, the ‘Valery’ and ‘Grande naine’ varieties are cultivated and 11% of the banana plants are fruits that meet the quality standards for exportation. The remaining 89% is unused organic matter from the harvest process that fall into two categories: fibrous waste (rachis, leaf and pseudostem) and non fibrous (fruit and male bud). These residues could generate derivative products, with a view of utilizing the whole plant.

In this research, the pseudostem of ‘Valery’ and ‘Grande naine’ from the Urabá Antioqueño zone was analysed for its potential to produce derivative products. The varieties were not evaluated separately and were treated as homogenous. The fibres in the pseudostem were extracted by using a mechanical process. The fibres and residues generated during the extraction process were characterized to determine their potential. The fibres were washed to remove the vegetal material present on its surface. The methods tested were tap water, aluminium sulfate hydrated at 1% and 5% and a non ionic detergent at 1% and 5%. The most effective methods were hydrated aluminium sulfate at 5% and tap water because they removed most of the vegetal material and did not affect the colour noticeably.

The fibres were composed mainly of cellulose (68%) and other components such as hemicelluloses (10%), lignin (9%)...
and pectin, water soluble compounds, fat and wax (13%). As a result, they could be used to produce special papers (e.g., tea bag, sausage skin and filter paper) and cellulose derivatives (e.g., carboxymethyl cellulose, rayon, cellophane). Chemical tests established that the fibres are resistant to alkaline substances and moisture, among others. Mechanical tests highlighted possible applications for the fabrication of tissue and packing material.

The characterization of the residues generated during the fibre extraction process determined that they could be used to generate a large quantity of products (e.g., animal feed, flour, compost) because of their high concentration of fibres (25% of dry weight), nitrogen free extracts (48% of dry weight) and minerals (N: 0.6% of dry weight, P: 0.1% of dry weight and K: 10% of dry weight).

Source: A. Gaviria et P. Gañán

Grupo de Investigación en Nuevos Materiales of the Universidad Pontificia Bolivariana Medellin, Colombia, e-mail: frojo@upb.edu.co

## Occurrence of *Meloidogyne incognita* on *Ensete superbum*

The family Musaceae has two genus, *Musa*, which contains all the cultivated varieties, and *Ensete*, which has six species. *Ensete superbum* is a wild and seeded ornamental banana species commonly grown in parks, dam sites and botanical gardens where humidity and rainfall are high (Figure 1).

Surveys undertaken in June 2002 to map the occurrence and distribution of plant parasitic nematodes infesting bananas in the southern part of Tamil Nadu revealed unusual yellowing and stunted growth in *E. superbum* grown at the Pechiparai dam in Tamil Nadu, India.

Soil and root samples were collected from the rhizosphere of *E. superbum* and the samples were processed according to the method in Hussey and Barker (1973). Almost the entire root system was parasitized by a root-knot nematode, which was identified as *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949.

The observation of the egg masses produced by the root-knot nematode revealed the presence of the parasite, *Paecilomyces lilacinus* (Figure 2), which has been reported as a potential egg pathogen of root-knot nematodes (Jatala 1986).
New dates of Congress on *Musa*

The international congress on *Musa*: harnessing research to improve livelihoods, previously announced to take place in May 2004, in Kuala Lumpur, will be held on 6-9 July 2004 in Penang, Malaysia.

The deadline for reception of accommodation form and fee payment is 1 March 2004. For more information, consult our website or contact Karen Lehrer at INIBAP HQ in Montpellier (k.lehrer@cgiar.org).

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This investigation is the first mention of the parasitism of *M. incognita* on *E. superbum* in India.

*Source*: P. Sundararaju, I. Cannayane and S. Sathiamoorthy of the Crop Protection Laboratory, National Research Centre for Banana, Tiruchirapalli – 620 102, India

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**References**


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The complete INIBAP team wishes you a happy year 2004!
Instructions to authors

INFOMUSA is an international journal published twice a year in English, French and Spanish. Our focus is to provide an outlet for research results and reports of interest to the Musa community. As INFOMUSA publishes articles on any Musa-related issue, authors should aim for simple and clear phrases that avoid unnecessary jargon in order to make their paper accessible to readers in other disciplines.

Manuscripts should be prepared in English, French or Spanish and should not exceed 2500 words, including references. They should be double-spaced throughout. All pages (including tables figures, legends and references) should be numbered consecutively.

Include the full name of all the authors of the paper, together with the addresses of the authors at the time of the work reported in the paper. Indicate also the author nominated to receive correspondence regarding the paper.

Manuscripts can be sent as e-mail attachments or put on a 3.5-inch disk for PC-compatible machines. Please indicate the name and version of the word processing software used and the author's e-mail address. In either case, we will need to receive by mail two printed copies of the manuscript.

Title: The title should be as short as possible and should not have numbers, acronyms, abbreviations or punctuation. Abstract: An abstract, not exceeding 200-250 words, should be provided. It should concisely summarise the basic contents and should be sent in the same language as the manuscript. Translations (including the title) into the two other languages should also be sent if this is possible. Key words: Provide a maximum of six key words, in alphabetical order, below the native-language abstract.

Introduction: The introduction should provide the rationale for the research and any relevant background information. Since it is not meant to be an exhaustive review of the topic, the number of references should be kept to a minimum. Introductions on the importance of bananas as a staple food or a traded commodity should be avoided, unless they are absolutely necessary for the comprehension of the article.

Materials and methods: The authors should provide enough details of their experimental design to allow the reader to gauge the validity of the research. For commonly used materials and methods, a simple reference is sufficient.

Results: The unit should be separated from the number by a single space and follow SI nomenclature, or the nomenclature common to a particular field. Unusual units or abbreviations should be defined.

Present data in the text, or as a figure, or a table, but never in more than one of these ways. Avoid extensive use of graphs to present data that could be more concisely presented in the text or in a table. Limit photographs to those that are absolutely necessary to show the experimental findings.

Discussion: The discussion should not contain extensive repetition of the results section nor should it reiterate the introduction. It can be combined with the results section.

References: All references to the literature made in the text should be referred to by author(s) and year of publication (e.g.: Sarah et al. 1992, Rowe 1995). References to not widely circulated documents, such as annual reports, and citations of personal communications and of unpublished data should be avoided. A list of references, in alphabetical order, should be provided at the end of the text.

Please follow the style shown below:


Illustrations and tables: These should be numbered consecutively and referred to by these numbers in the text. Each illustration and table should include a clear and simple caption. Figures and tables should be inserted after the references or in separate files.

Graphs: provide the corresponding raw data with the graphs, if possible in Excel format.

Drawings: provide originals if this is possible.

Photographs: We prefer hard-copy printouts of photographs (bright paper with good contrast for black and white photographs; good quality proofs and films or original slides for colour photographs), but please remember that we will not return them. We will publish pictures that have been scanned or taken with a digital camera as long as the resolution is high enough (1 million pixels or a minimum of 300 dpi when the photograph is in real size). Acceptable file types are JPEG, TIFF and EPS. Avoid sending photos inserted in a Word or Power Point document, unless they are accompanied by a better quality alternative.

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

Cultivar names: The name of the cultivar should be placed between single quotation marks. If the name is a compound noun, only the first word starts with a capital letter, unless the other refers to a place or person. Use the most commonly agreed upon name, such as 'Grande naine' and avoid local variations or translations, such as ‘Gran Enano’.

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.
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