musae being the main pathogen. Additionally, *Fusarium* spp. are ubiquitous secondary invaders and *Acremonium* sp., *Botryodiplodia theobromae*, *Fusarium moniliforme*, *Fusarium pallidoroseum* (formerly *F. semitectum*), *Nigrospora sphaerica*, *Penicillium* spp. and *Verticillium* spp. are of regional importance. These secondary invaders are often isolated from severely diseased fruit in higher frequencies than *C. musae* and therefore blamed as the causal agent. However, whenever quantitative inoculation studies were carried out in order to fulfil Koch's postulates, *C. musae* required at least one log unit less inoculum than the other fungi to evoke symptoms.

Colletotrichum musae establishes a latent infection in the field at early stages of fruit development. When the banana hands are severed from the rachis during harvest, spores of fungal inoculum enter the wound and initiate disease development at this window of opportunity. Crown rot symptoms usually only become visible during fruit ripening in the countries of destination. Then, however, the disease can progress rapidly and, in severe cases, the rot penetrates the pulp which renders the fruit unmarketable. Crown rot causes losses of 2-10% in all banana-exporting countries. Its incidence rises periodically in the rainy season.

Other post-harvest diseases include anthracnose, also caused by *C. musae*, cigar-end rot caused by *Trachysphaera* and *Verticillium* spp., finger rots caused mainly by *B. theobromae, Ceratocystis paradoxa, Pestalozzia leprogena, Phomopsis* sp. and *Sclerotina sclerotiorum,* and squirter disease associated with *N. sphaerica* in combination with physiological stress factors. Other fruit spots caused by *Cercospora hayi* and *Deightoniella torulosa,* and pitting disease caused by *Pyricularia grisae* are more accurately regarded as field diseases but symptoms exacerbate after harvest. Also, the boundary between field and post-harvest diseases is gradual because many post-harvest pathogens can establish asymptomatic infections in the field.

Crown Rot Control

Crown rot is commercially controlled by the fungicides thiabendazole (TBZ) and imazalil, alone or in combination, applied as a post-harvest dip or spray. Cross-resistance to benomyl, formerly used in Sigatoka control, renders TBZ relatively ineffective in many traditional banana areas. Other fungicides have been tested on an experimental scale but are not registered for use on export bananas. Several projects have addressed non-chemical control options for environmental concerns as well as the health of banana workers and consumers. Breeding programmes, most notably at FHIA (Fundación Hondureña de Investigación Agrícola) in Honduras, have produced crown rot-resistant hybrids but these have different organoleptic characteristics from Cavendish clones and are not well accepted by the mainstream customer.

Cultural management options include reduction of inoculum and earlier harvesting which is sometimes combined with techniques that accelerate fruit development in order to minimize yield loss. Physical approaches require first and foremost a rapid cooling of the fruit after harvest and a continuous cooling chain throughout transit which should be of minimum duration. Due to the highly perishable nature of banana fruit, the chain of operations has to be well organized at all levels. Smooth crown cuts and immediate transfer of fruit into an alum solution for delatexing also reduces crown rot. During shipment, modified and controlled atmospheres have shown promise but many of them either proved too expensive for routine use or had negative side effects on other fruit quality characteristics. Natural and non-synthetic chemicals have been investigated, among them calcium preparations, plant extracts, organic acids and waxes. One of the most promising compounds, a citrus seed extract, is now rarely used because of its inconsistent effect, possibly due to the low shelf-life of the product. Alginate-calcium gels reduced crown rot under experimental conditions. They are likely to form part of an integrated approach with biological control rather than on their own.

Among the biological options, induced systemic resistance and antagonists have been tried. Induced systemic resistance is operational in a wide range of crops but has not yet been exploited in any post-harvest situation. However, culture filtrates or cell wall fragments of *C. musae* induce the production of antifungal components in the peel of green banana fruit. As a result, conidial germination of *C. musae* was inhibited on treated skins. Subsequent attempts to employ the more easily obtainable dead conidia of *C. musae* as a resistance-inducing post-harvest treatment were unsuccessful. However, as a pre-harvest treatment (injection of the rachis 1-2 weeks before harvest) high crown rot levels could be reduced to *ca* 70% of control. More data, however, are required to substantiate and quantify these tendencies.

A programme funded by ODA (the UK Overseas Development Administration, now DFID, the Department for International Development) and managed by NRI (Natural Resources Institute, UK) in the Windward Islands identified several indigenous organisms with potential for biological or integrated disease control. Whereas only few bacteria appeared effective, mycoparasites (fungi parasitizing other fungi) showed great promise. Some of them attacked the whole range of fungi involved in the disease complex, including structures which are very resistant to fungicidal attack such as conidia and haustoria. Others showed great tolerance to fungicides themselves and could thus be combined with reduced concentrations of fungicide in an integrated disease management system. The highly diverse population structure of *C. musae* renders a single-strain biocontrol agent unlikely to provide consistent crown rot control. However, mixtures of strains could overcome this problem. Each mycoparasite was found to act via a different main mechanism, i.e. parasitism, antibiosis, competition. Combinations of up to four strains of mycoparasites belonging to different species (mostly *Gliocladium* spp. and *Paecilomyces* spp.) complemented each other and progressively increased the biocontrol efficacy against mixed infection. Preliminary studies suggest that incompatibility is not a problem. Future research should thus focus on mycoparasite mixtures in compatible formulations such as alginate-calcium gels.

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Alternatives to Chemical Control for Anthracnose in Guadeloupe

Anthracnose of bananas, caused by *Colletotrichum musae*, is the most important postharvest disease affecting the quality of exported fruits from the French West Indies. This disease develops during fruit conservation and ripening and it depreciates the fruit marketability. Anthracnose is in practice controlled by a postharvest fungicide. However, under Guadeloupe conditions, this chemical control has now reached deadlock for three main reasons:

(a) aerial fungicidal sprays to control Sigatoka disease have resulted in the appearance of strains resistant to the active ingredients used for anthracnose postharvest control; (b) fungicidal treatments are not effective in all production zones, quite apart from the appearance of resistance; (c) consumer demand is for a reduction in pesticide use, especially those applied postharvest. So, there is a need for new control strategies, and these could be developed from a better knowledge of the bioecology of the pathogens.

Disease expression is dependent on a number of factors present at different steps in banana production, from fruit production in the field, to fruit packing, transport and conservation, maturation in ripening rooms, and marketing. Of these, the variation in potential fruit quality at the field level is particularly important, since it is responsible for seasonal (disease is more severe from September to January) and spatial (disease is more severe in low altitude lands of Guadeloupe) variations. Potential fruit quality is governed by a physiological (fruit susceptibility) and a phytopathological (level of fruit contamination) component. Recent work has been carried out in Guadeloupe on these two components in order to propose alternative strategies to chemical postharvest control.

The Physiology of Fruit Susceptibility

A diagnostic survey was conducted on 106 banana plots in order to identify the factors which might explain variation in fruit susceptibility to wound anthracnose as measured through artificial inoculation at flowering and wounding the fruit at harvest. This study showed that fruit susceptibility varies widely with pedoclimatic conditions and farming practices.

In the pedoclimatic area of halloysitic and ferralitic (low altitude) soils, where fruit anthracnose lesions developed most (54 plots), a relationship was found between the manganese (Mn) content of fruit and susceptibility to anthracnose: the plants producing the most susceptible fruit had higher foliar Mn concentrations and lower calcium (Ca) concentrations, and had grown on rather acid soils.

It is possible that the high Mn content of the fruit could have arisen from stress situations which could reinforce the ability of the fruit to synthesize ethylene, a hormone that can play a very important role at different levels in the host-pathogen interaction. It has been shown that ethylene activates germination, formation of appressoria and lesion extension. Anoxic conditions resulting from soil compaction or bad drainage can lead to a reduction of different forms of manganese into Mn^{2+} in the soil, and to a massive absorption of Mn^{2+} by the plant, accompanied by a lowering of the leaf Ca^{2+} content. For many plants, it has been shown that root anoxia causes ethylene synthesis by the plant shoots. It is then possible that the fruit from banana plants subjected to anoxic conditions may have a greater ability to synthesize ethylene. Work is still in progress to test this hypothesis experimentally in order to manage fruit susceptibility to anthracnose through optimized farming practices.

The Phytopathology of Fruit Contamination

Fruit pollution occurs in the field. Conidia germinate rapidly and form a melanized appressorium which remains inactive until the fruit ripens. A penetration hypha then develops and the mycelium enters the skin and later the fruit pulp, forming brown lesions. Once quiescent infections are formed, the pathogen is permanently installed on the host because dark appressoria can survive very adverse environmental conditions. So, potential fruit quality depends on the quantity of conidia that reach the fruit surface (fruit pollution) and the quantity of conidia that form a dark appressorium (fruit contamination).

Fruit Pollution

Colletotrichum musae does not sporulate on the green parts of the banana plant but only on senescent organs. We have conducted studies in order to (a) identify the inoculum sources contributing mostly to fruit pollution; (b) determine the dynamics of fruit pollution from flowering to harvest; (c) establish the mode of transport of this inoculum to the surface of the fruit; and (d) evaluate the effect of covering the bunches with a plastic sleeve on fruit pollution.

Fruit pollution occurs mainly from inoculum produced on the floral parts and the last bunch bract. Because they are closest to the fruit, the floral parts are the most effective inoculum source for fruit pollution. The elimination of the floral parts and of the last bunch bract at the flowering stage reduces considerably the quantity of conidia trapped, from flowering to harvest, in rainwater run-off under the bunches, and the level of fruit contamination measured at harvest. Moreover, *C. musae* is readily isolated from floral parts.

Fruit pollution occurs mostly during the first month after bunch emergence (the critical period) and strongly decreases thereafter. Most conidia were trapped in rainwater run-off under the bunches during this critical period. Most inoculum was isolated from the floral parts during this period. Lastly, the climatic conditions prevailing during this critical period were related to the levels of fruit contamination observed at harvest and to the cumulative number of conidia trapped in rainwater run-off from flowering to harvest.

In the absence of rainwater, inoculum is not dispersed and does not reach the fruit surface. All the floral parts of bunches from plants grown under rain-out shelters were inoculated with *C. musae* conidia and a large amount of inoculum was isolated from them. No anthracnose lesions were observed on the fruit at harvest.

Sleeving of bunches limits rainwater runoff and inoculum dispersal to the fruit surface. A reduction of more than 80% in the level of fruit contamination is observed on sleeved bunches compared with unsleeved bunches, even though there is no effect on inoculum production by the floral parts.

Fruit Contamination

We developed a methodology to assess the level of fruit contamination through the number of anthracnose lesions that develop on fruit (the technique is applicable to immature fruits aged 4 weeks). A good correlation between the number of anthracnose lesions and the quantity of appressoria is achieved when the fruit are conserved at high temperatures with elevated levels of ethylene.

The formation of melanized appressoria was evaluated, with a constant inoculum concentration, in controlled temperature and humidity conditions close to the natural contamination. The presence of free water is essential and appressoria formation does not occur within six hours. This indicates again the importance of rain or long dew periods for contamination.

Alternatives to Chemical Control

The above results suggest there are a number of strategies for managing anthracnose at various stages in the production system that could be investigated as alternatives to chemical postharvest control.

1. At the Field Level. Fruit pollution can be reduced by removing the floral parts and the last bunch bract. The operation must be carried out as soon as possible to minimize inoculum development. This practice, combined with sleeving bunches, gives a very significant reduction in the level of contamination of the fruit. Particular attention must be paid to early sleeving, which should be done before the fingers reach a horizontal position (or before all bracts have fallen). A better knowledge of the regulation of ethylene biosynthesis would allow farming practices to be developed which could improve fruit resistance to anthracnose.

2. In the Packing Station. Fruit must be handled carefully during transport to the packing station and packaging in order to avoid bruising, as this enhances disease expression. Maintaining good quality for the water used in de-handing and in the washing tanks is also important to avoid contamination of crowns. Lastly, packing the fruit in polybags allows the formation of a modified atmosphere (higher CO_2 and lower O_2 content), which is important to improve fruit conservation and slow down fungal development.

3. In Ripening Rooms. The quantity of ethylene used in the ripening rooms, as well as the time of ethylene contact and the temperature of fruit conservation can increase disease development during fruit maturation. Present practices should be reconsidered: high ethylene rates (>1000 p.p.m.) are used even though small rates (1 p.p.m.) can induce the climacteric rise.

Testing the Alternatives

The possibility of eliminating postharvest treatment through these different non-chemical measures will be evaluated in a trial on pilot farms. The level of fruit contamination at harvest will be forecast using the assessment test on 6-week-old fruits, and actual contamination will then be assessed. These results will provide useful feedback on the performance of the new measures.

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Training News

In this section we welcome all your experiences in working directly with the end-users of arthropod and microbial biocontrol agents, or in educational activities on natural enemies aimed at students, farmers, extension staff or policymakers.

Feedback on Farmer Field Schools

Since 1998, we have reported on many participatory training and research initiatives around the world. In this issue, we are revisiting two programmes based on the Farmer Field School (FFS) approach, to report on what has happened since, and see if there are any general lessons to be learned. A message that comes through clearly in both these studies is that farmer commitment to biocontrol and IPM remains high, but follow-up training is crucial (for both trainers and farmers) to reinforce understanding of IPM and fill in the inevitable gaps in knowledge.

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Keeping off the Treadmill

We begin with an update to the first article to be published in 'Training News' [*BNI* **19(2)**, 41N-42N, 'Stepping off the cotton pesticide treadmill']. The article described how, in 1997, a farmer participatory training programme involving Training of Trainers (TOT) and Farmer Field School (FFS) approaches had enabled cotton farmers from Vehari District of Punjab Province in Pakistan to become IPM practitioners. The trained farmers made decisions that lowered their input costs by 68% while maintaining or even increasing crop yield and quality.

The continuing impact of the programme was assessed at the beginning of the 1999 growing season. The aim was to find out what the FFS graduates were doing 2 years on – what aspects of training they were confident in and what needed reinforcing. A survey revealed that of the ten FFS farmer groups trained in 1997, five were still very active. At least 80% of the graduates were still involved in active FFS groups and the most visible effect of the training was that they were familiar with various stages of pests and beneficials and many were conducting agro-ecosystem analysis (AESA) in their own fields, outside the group sessions. At the five other sites, FFS groups were less active but insecticide application remained much reduced compared with before the training.

There was evidence for limited spread of IPM concepts and practices to farmers in districts neighbouring those targeted by the participatory research programme, although not sufficient to enable new farmers to carry out IPM in practice. Some of the farmers in adjacent districts who were interviewed were familiar with some beneficials, and even more were familiar with IPM terminology. But they had no understanding of the concepts, or how to practise IPM. It was concluded that insufficient dissemination of IPM technology had taken place to give untrained farmers a sound basis for changing their management practices.

Interviews were conducted with 15 FFS graduates from 1997 and 15 untrained farmers in each of the five localities where the FFS groups were still most active to assess farmer perceptions of the effectiveness of FFS training and IPM. The findings were used to revise the curriculum for 1999.

FFS training in 1999 was carried out in close collaboration with five community-based organizations (CBOs) coordinated by the NGO Catholic Relief Service. Five trainers from each CBO, many of whom are cotton farmers themselves, were trained as FFS facilitators, each taking responsibility for facilitating activities with five farmers in each FFS group. Good local networks have been built up as a result of this community-level participation and their effectiveness was demonstrated by the fact that over 90% of non-participating farmers in the five FFS communities also reduced or eliminated insecticide application on their cotton in 1999.

During the 1999 season, FFS groups again avoided early season insecticide application in all plots and were able to eliminate chemical control altogether in some of the IPM plots. Net profits for IPM and farmers' practice plots averaged 16,451 and 11,413 Rupees/ha, respectively, confirming again the economic benefits of IPM for a second season. In the Punjab context it is critical for FFS projects to convince farmers and extension staff that IPM can be viable over a range of pest pressure, climate and economic variability. However, there is now acceptance in wider circles in Pakistan of the FFS approach, and this recognition will help to facilitate implementation of future cotton IPM programmes.

When farmers were questioned about current problems in cotton production, high price of cottonseed was identified as the most severe constraint at all five sites, and at three sites pest control came second. However, at the other two, pest control was not considered a main issue, and most FFS-trained farmers said that the presence of beneficials meant that there was no need to apply insecticides. Most trained farmers at all sites were familiar with various, if not all, stages of pests and beneficials, while untrained farmers were overwhelmingly not. At one locality, most trained farmers had also retained an understanding of IPM terminology, its philosophy and importance. At other localities, the farmers' level of familiarity had dropped considerably, although it still greatly exceeded that of