good governance, transparency, knowledge management, creativity and empowerment.

Lois Englberger's talk on carotenoid levels in cultivars from Micronesia (see INFO*MUSA* 12(2):2-5) drew a lot of interest, not only from the participants but also from the media. Her data show that some traditional varieties contain enough provitamin A carotenoids at realistic consumption levels to prevent Vitamin A deficiency (VAD), a major cause of debilitating health problems in developing countries and a significant contributor to infant and maternal mortality. Lois also pointed out that there are many yellow- and orange-fleshed bananas in other countries – such as 'Pisang raja', 'Pisang berangan', 'Pisang mas', 'Champa' in Bangladesh, 'Nendran' in India and 'Lakatan' in the Philippines – which could have an impact on eliminating VAD and improving general health.

Finally, a number of speakers from Africa and Asia presented national and local initiatives to foster the development of banana enterprises. The abstracts of the oral presentations and posters are available on INIBAP's website at www.inibap.org.

Focus on bacterial wilt

How can the advance of banana xanthomonas wilt be halted?

Since its detection in central Uganda in 2001 (Tushemereirwe *et al*. 2003), banana xanthomonas wilt disease (BXW, also referred to in Uganda as banana bacterial wilt) has spread to at least 21 districts throughout the eastern, central and north-western parts of the country, probably mediated by airborne (most likely insect) vector(s). Although the distribution within these districts is still localised and patchy, the disease is rapidly filling in the gaps. It is also moving south and westwards towards some of the most important banana growing areas in the country that are not yet affected. All of the commonly grown genotypes are succumbing to this new disease, which destroys the fruit bunches and can reduce yields to zero, threatening the livelihoods of millions of people. An outbreak has also recently been confirmed in the North Kivu region of the Democratic Republic of Congo (see *Musa*news), and the disease is poised to enter Rwanda, Kenya and neighbouring countries. There is increasing public awareness of the plight of those who have already suffered severe hardship from the disease and concern for those at risk.

BXW has many similarities to bacterial wilts of banana in other parts of the world (Moko, blood, bugtok diseases) that are caused by *Ralstonia* (formerly *Pseudomonas*) *solanacearum* and closely related organisms (Thwaites *et al.* 2000). Control depends on measures that are designed to reduce disease infection and to rehabilitate areas that are already infected (*i.e.* management), and to reduce or prevent the spread of disease to areas that are not yet infected (*i.e.* containment). Experience with these diseases shows that once they have become established in smallholder banana cropping systems, then control is very difficult and

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Figure 1. Affected mats do not always die, so once the disease has become established in smallholder production systems, it is very difficult to eradicate.

eradication effectively impossible (Figure 1). Farmers and consumers have to get used to massively reduced yields. Interventions in these “zones of occupation” need to focus on helping farming communities to manage, or learn to live with, the disease, including introducing alternative crops and food staples and gaining their acceptance. This will be a daunting task in Uganda, emphasizing the importance of containment.

Disease containment depends on two key actions: promptly removing sources of inoculum; and reducing or eliminating opportunities for spread. These are mutually reinforcing: the greatest degree of control will be obtained when infection sources are eliminated promptly and the risks of transmission are reduced. Many sources of infection are known or suspected for BXW, including standing infected plants, plant residues, contaminated soils and water, and traded products (fruits, leaves and planting materials). The contribution these sources make to the spread of the disease depends on the survival of bacteria and the mode (and probability) of transmission. Although the relative importance of many of these factors is unknown, tentative conclusions about factors likely to be most important for disease containment can be drawn from field observations on the behaviour of the disease in Uganda and from knowledge of other banana bacterial wilts. A remarkable feature of all these diseases is that infection appears to occur via the male bud, probably following transmission by flying insects that collect or feed on nectar and pollen. Although it is not known at present whether the same or similar insects are involved, this is a striking example of parallel evolution: at least three taxonomically distinct pathogens of banana appear to have evolved a similar mechanism of transmission on different continents. Fortunately, this also presents similar opportunities for controlling the spread of disease[1].

Observations at advancing disease fronts in Uganda suggest that transmission to the male bud is the primary means of spread. Not only are diseased buds often the first symptom to be observed but these are also most commonly seen on ABB banana types, which are known to be particularly susceptible to insect transmission in other banana bacterial wilt diseases (Buddenhagen and Elsasser 1962). This suggests that, as with these other diseases, airborne infection via male flower parts is the main mechanism driving the current epidemic. Thus timely removal of the male bud should interrupt the transmission cycle and prevent the spread of the disease, especially if this can be done in those types that are considered to be at greatest risk to infection via thus route.

Herein lies the main challenge for controlling the epidemic in Uganda where the ABB type ‘Pisang awak’, known locally as *kayinja*, is widely grown for the production of “banana beer”. At the margins of the disease front, and throughout areas already affected, *kayinjas* and other ABB types such as ‘Bluggoe’ (*Kivuvu*) can be found with typical symptoms of inflorescence infection (Figure 2). Farmers themselves have come to recognise that these are usually the first types to become infected. Control options seem obvious enough – reduce the rapid rate of spread by destroying, or at least debudding, the ABB types and then concentrate on preventing other modes of spread (contaminated tools, infected plant materials) and clean up areas already infected. Unfortunately however, plots

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Figure 2. Infected male bud.

[1] See discussion forum at http://www.banana.go.ug/cgi-bin/discus/discus.cgi

of *kayinjas* are frequently neglected or at best semi-cultivated and whilst harvesting rights may be established by local custom, ownership and responsibility for maintenance is often obscure. Under these circumstances, it is understandably difficult to persuade individual farmers to debud healthy plants or to cut down or destroy mats that have become diseased but may still produce the occasional usable bunch of fruit – let alone to remove plots of *kayinjas* that are not yet affected. Financial inducements or compensation are unlikely to be feasible given the magnitude and continuing nature of the problem, and the costs and logistics involved. Can some form of community awareness and action succeed, perhaps backed by coercion or enforcement? And to what extent can individual farmers take action to protect their own banana plantings for themselves?

Two broad approaches can be suggested: firstly, a series of *cordons sanitaires* at the margins or "disease fronts" of the epidemic, involving intensive control measures including phytosanitation, eradication of all diseased plants, debudding of healthy ones, and strict controls on the movement of people and planting materials. This would require actions both within and in advance of a diseased area in order to create a "firebreak", or zone of zero tolerance of both sources of inoculum (diseased plants) and infection courts (male buds). Given the difficulties of managing *kayinjas*, a high degree of community participation, mobilisation and support would be required. The resources necessary to achieve this may be justified when the stakes are particularly high, as for instance in preventing further movement of the disease to the intensive banana cultivation areas in southwest Uganda. Even so, it is difficult to conceive of the high levels of adoption (and enforcement) of control measures that are likely to be necessary on the broad front over which the disease is progressing.

The second approach depends on what individual farmers can do for themselves. Farmers may be able to do little to control sources of infection (and hence inoculum) that surround their own plants, but they can take steps to prevent their bananas from becoming infected through their own actions (use of contaminated tools, footwear, planting materials) and by preventing airborne spread. The question, as yet inadequately untested, is how effective are such individual courses of action. Can individual farmers, with fields of on average no more than 1-2 ha, prevent the disease from becoming established by debudding on such a small scale? At present, the experiments remain to be done but the stakes are high. If only a small proportion of farmers were to succeed by adopting such measures, then others would surely follow and "green islands" would emerge amidst the surrounding devastation. The evidence is certainly encouraging: unconfirmed reports suggest that some farmers have greatly reduced or even prevented the spread of disease in their fields since adopting debudding, cutting out infection and other phytosanitary measures. As reported in this issue's *Musa*news, it is surely no accident that Dwarf Cavendish, a variety with floral morphology resistant to insect-borne infection, survives virtually unscathed alongside diseased *kayinjas* in Ethiopia. Can it be coincidence that in the Congo, where inflorescence infection appears to be rare, the disease has so far spread slowly?

Whilst prevention of airborne dispersal of the bacteria between inflorescences may be the most important means of controlling the primary spread of the disease, especially between farms and villages, other modes of infection undoubtedly occur and are critical to containment. The necessary measures can be summarised as follows:

- Intensive surveillance and reporting to identify the current disease distribution and presence of suspected new outbreaks;
- Prompt follow-up actions to investigate reports of new outbreaks and to take action to eradicate or neutralise them;
- Strict control on the movement of plant materials from diseased to non-diseased areas, especially planting materials;
- Availability and strict observance of phytosanitary practices, especially disinfection of cultivation tools, footwear etc.;
- Strict control of infection, and preferably total destruction, of ABB types at the disease front;
- Strict enforcement of debudding of all types at, and in advance of, the disease front by breaking off (not cutting) the male buds as soon as the last fruits have set.

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Thesis

Effect of soil compaction on the architecture of the banana root system growing in an andosol

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PhD thesis submitted in 2002 to the *Institut National Agronomique Paris-Grignon* and the Avignon *Institut National de Recherche Agronomique*, France

Despite the coexistence of several banana production systems in the West Indies, mechanized monocultures remain important. Heavy machinery, soil tillage and frequent planting lead to the degradation of soil structure and decreased soil fertility, while monoculture favors pests. Andosols are very frequent in the traditional banana growing area of Guadeloupe and naturally promote the development of the root system. However the dynamics of soil colonization by banana plants remain largely unknown and as a result cultural practices cannot be adapted to the uptake and anchoring abilities of the roots. Experiments were conducted to characterize the architecture of the banana root system three months after plantation in an andosol.

Experiments in rhizotrons, containers, and in the field helped determine the parameters pertaining to four main functions: root emission, root growth, root branching and senescence. Root emission was fairly similar to what is observed in other monocotyledons, like maize and rice, and was correlated with shoot development. The diameter at the root apex increased between planting to emission and changed over the life of the root. Two original methods based on static morphological observations were used to determine the *in situ* root growth rates. The root growth rates ranged from 0.1 cm/day in quaternary roots to *3.5* cm/day in primary roots and were closely related to the diameter at the apex. Root branching was almost strictly acropetal (from base to apex). The density of root branching was less the further away from the base of the root and the smaller the diameter of the main root. Root senescence was not explicitly characterized, but is related to the duration of the growth phase of the root, which seems proportional to its mean diameter.

The impact of soil compaction on the architecture of the root system was studied in pots (static compaction with an hydraulic press) and in the field (dynamic compaction with tractor wheels) to study the response of the roots to pressures ranging from 50 kPa to1200 kPa. A slight decrease in the growth of dry matter in shoots was observed when the soil was highly compacted. Only the growth of the large roots was affected by a lower soil macroporosity: an 8% reduction in total porosity (corresponding to a 65% reduction in air filled spaces) reduced their growth rate by 50%. A multiple linear regression between growth rate and three factors (diameter at the apex, soil porosity and total degree days) accounted for 92% of the observed variance. Soil compaction increased the death rate of primary roots by a factor of 4 but did not globally affect root trajectory, which tends to be horizontal. Roots growing in compacted soils had a more tortuous trajectory.

A model of the architecture of the banana root system was built to simulate the development of the root system under various soil conditions. Once validated, this model could help understand the effect of various mechanization scenarios on root absorption and the stability of the plant.