

Banana and plantain IPM in Cameroon: progress and problems

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Introduction

Bananas and plantains are major staple foods as well as important source of revenue for a significant proportion of the Cameroonian population. About 1 700 000 tonnes are produced annually (1 000 000 tonnes plantains and 700 000 tonnes bananas). Plantains are produced by resource-poor farmers, generally in a mixed cropping system with cash crops (coffee, cocoa) or with food crops (cocoyam, cassava, maize, tania, legumes). Plantains are found throughout the southern part of the country between 0 and 2000 masl. Several plantain cultivars are grown: French types are dominant in the highland areas (>1000 masl) whereas false horn and true horn are dominant in the lowland zones. Export bananas in contrast are monocropped and are produced by large-scale growers. The total area under export banana cultivation is about 5000 ha and these plantations are located in the Fako and Moungo divisions on volcanic soils between 0 and 500 masl. Several pests and diseases are found in both cropping systems. The most important pests are the banana borer weevil (*Cosmopolites sordidus*) and the nematodes *Radopholus similis* and *Pratylenchus goodeyi* (Fogain 1994, Bridge *et al.* 1995). Black and yellow Sigatoka due respectively to *Mycosphaerella fijiensis* and *M. musicola* are the most devastating diseases (Mouliom Pefoura 1984). Other phytosanitary problems are cigar-end rot disease caused by *Trachysphaera fructigena* weeds and thrips on fruits.

This paper gives the distribution and the importance of the major phytosanitary problems in Cameroon and IPM control measures developed or currently under investigations.

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The banana borer weevil

Distribution and importance

Three species of weevils are found in banana plantations in Cameroon: *Cosmopolites sordidus*, *Metamasius sericeus* and *Pollytus melleborgi*, but *C. sordidus* seems to be the only weevil of economic importance (Fogain 1994). *Cosmopolites sordidus* was first reported in the country in 1947 by Carayon (Mendjime 1982). The insect is found in all the banana- and plantain-producing areas in Cameroon (Fig. 1). The percentage of occurrence varies between 50 and 90% (Fogain 1998a). A survey carried out in all the banana- and plantain-producing areas showed that 82.5% of the farmers are aware of the weevil problem and are capable of recognizing damage caused by the insect. Severe damage is observed in small-scale plantain farms compared to commercial plantations of Cavendish. In some areas such as southwest Cameroon, it is difficult to grow plantain if no protection against the weevil is available. For example, investigations undertaken in a peasant plantation comparing plantains and Cavendish showed that damage due to the weevil can be up to 77% on young plants of plantains and only 20% on Cavendish clones six months after planting in a highly infested zone of Ekona.

Integrated management of *Cosmopolites sordidus*

Several control measures including cultural, mechanical and chemical methods are used by farmers. In intensive cropping systems, plantations are renewed every 5 to 6 years and control measures against the banana borer weevil include crop hygiene, propping and guying, use of clean and disinfected suckers or tissue-cultured plantlets, and chemical treatment. In small-scale farming systems, some farmers use insecticides or wood ash but propping is the most common form of control.

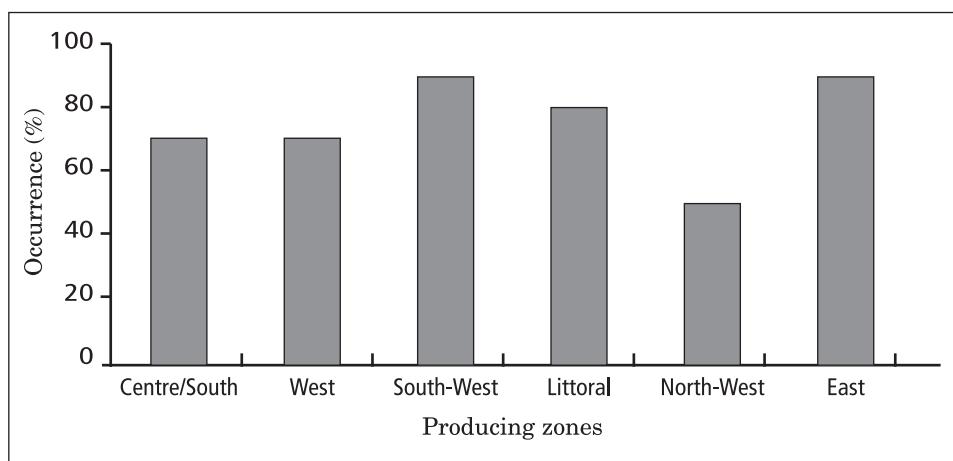


Figure 1. Occurrence of *Cosmopolites sordidus* in plantain-producing areas of Cameroon.

Cultural and mechanical control

Crop hygiene and the use of clean planting material are recommended to farmers, but only industrial growers apply these techniques. Removal of plant debris and destruction of old pseudostems to reduce breeding sites are sound techniques to reduce weevil populations. Trapping adult weevils using split pseudostems is also recommended. Propping and guying are common practices in small- and large-scale plantations to reduce toppling.

Chemical control

The use of insecticides to control weevil is the most popular control method, both in commercial and in peasant plantations. Insecticides are applied systematically 2 to 3 times a year (April, July and October) depending on the level of infestation. The insecticide Regent (fipronil) is the most commonly used. Continuous application of this compound may in the future lead to resistance as it is the only compound used by most growers. Some nematicides such as Terbuphos have insecticide activity and can therefore be used when the level of infestation is not too high.

Plant resistance

Several investigations have shown that different levels of susceptibility to *C. sordidus* exist within *Musa*. An evaluation of 52 accessions from the CRBP *Musa* germplasm revealed that most banana and plantain grown commercially are susceptible to *C. sordidus* (Fogain and Price 1994). Cavendish AAA and most of the ABB cooking bananas are however less susceptible than most of the plantain AAB clones. The triploid AAA Yangambi Km5 and the diploids Calcutta 4, *Musa balbisiana* and Truncata have a good level of resistance to the insect (Fogain and Price 1994, Mohaman 1998).

Current investigations are carried out in the following areas but most of the results obtained, however, have not yet been transferred to farmers.

Botanical insecticides

Studies on the use of neem (*Azadirachta indica*) against *C. sordidus* were initiated in 1993. *In vitro* tests showed a significant reduction of weevil population with neem powder. Under field conditions the most interesting results were obtained with a corm dipping treatment at the rate of 2 kg of neem powder in 10 litres of water (Fogain and Ysenbrandt 1998).

Use of antagonists

The banana borer weevil has several natural enemies. Surveys in banana and plantain producing zones of Cameroon revealed the presence of entomopathogenic fungi. A local strain of the fungus *Beauveria bassiana* was isolated in the country and several investigations *in vitro* have shown that the strain is pathogenic on adults of the weevil (Fogain 1994). Several strains of entomopathogenic nematodes have also been isolated and are currently being tested for their efficacy against the weevil. The use of these

biocontrol agents will be of interest to resource-poor farmers as most of them do not apply pesticides capable of affecting the antagonists.

Nematodes

Distribution and importance

The major nematode species associated with bananas in large-scale plantations are *Radopholus similis*, *Helicotylenchus multicinctus*, *Hoplolaimus* spp. and *Meloidogyne* spp. The nematode *R. similis* is present in all plantations and is by far the most important. Population levels vary in most cases between 2000 and 200 000 individuals per 100 g of roots. In areas where bananas are alternated with fallow, large populations of *Meloidogyne* are often found on roots of young tissue-cultured plants.

In extensive cropping systems, the major crop found is plantain AAB. The dominant species vary with the region. In areas at elevations below 700 m, *R. similis* is the dominant species, whereas at higher elevations (>1000 m) *Pratylenchus goodeyi* is dominant (Fig. 2). Between these two elevations, both species can be encountered. Other nematode species are *H. multicinctus*, *Hoplolaimus* spp., *Meloidogyne* spp. and *P. coffeae*. Results of a survey showed that only 22.2% of the farmers are aware of nematode problems and 5% can recognize nematode damage. Root damage is generally severe in this type of cropping system as replanting is not frequent and also because most resource-poor farmers do not apply nematicides. In the Centre and South provinces of Cameroon, more than 50% of the root samples collected showed severe root necrosis (Fogain 1998). Studies undertaken to evaluate yield loss of plantains due to the burrowing nematode showed that yield of the plantain French Sombre can be doubled when nematodes are controlled with three applications of nematicide a year (Fogain 1998a).

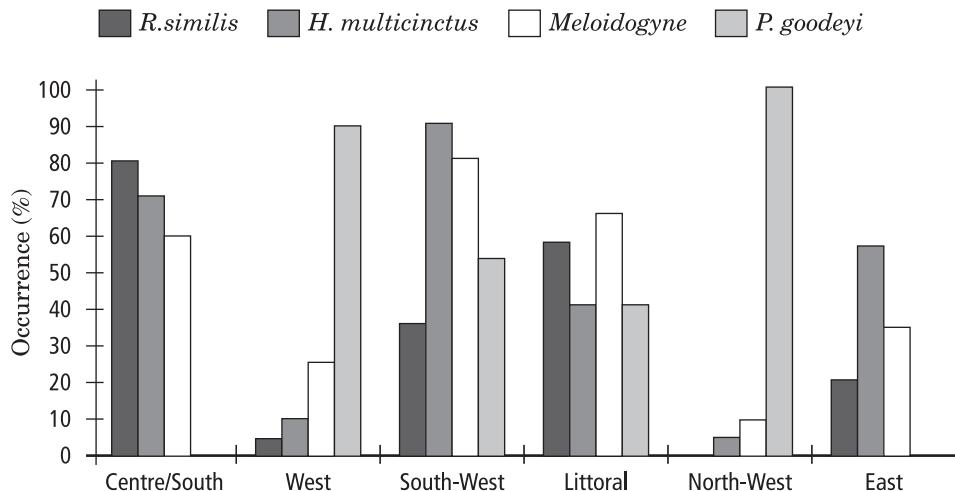


Figure 2. Occurrence of major nematode species of bananas and plantains in Cameroon.

Integrated management of nematodes

Although several control measures are recommended to farmers, nematode IPM in the whole country is only done by large-scale banana growers. Most resource-poor farmers generally do not apply IPM strategies for many reasons, in particular a lack of basic information on how to apply the technology, and financial resources to use them.

Use of clean planting material

The planting material is one of the most important source of dissemination of nematodes. Clean and disinfected suckers are recommended to farmers to ensure that the nematodes do not get into the field. In commercial banana plantations suckers are pared and dipped in a nematicide mixture before planting. Other methods such as hot water treatment for disinfection of planting material are not adopted by farmers. In small-scale plantations, farmers simply clean the corms and no dipping is done before planting. Tissue culture plantlets are also widely used by industrial banana plantations.

Cultural control

Fallow and crop rotation are widely used by commercial banana plantations because replanting is frequent. Studies undertaken in Cameroon have shown that infested land fallowed for 10-12 months results in considerable reduction of *R. similis* populations (Fogain *et al.* 1998). In some commercial plantations the fallow period is extended to 15 months. When tissue-cultured plants are used after fallow, very low populations of *R. similis* are recorded two years after planting. This is due to the fact that when the initial population of a pest is very low, it takes the pest longer to increase to damage threshold levels. Crop rotation with non-host plants such as sweet potato and pineapple is also recommended to farmers.

Chemical control

In commercial banana plantations, nematicides are systematically used in old plantations. In newly established plots, nematode populations are monitored monthly and decisions to apply nematicides are taken only when populations of *R. similis* are greater than 7000 individuals per 100g of roots. Several nematicides are available to farmers (cadusaphos, carbofuran, phenamiphos, terbuphos, oxamyl, etoprophos, isazophos) (Fogain *et al.* 1996). Three applications a year of nematicides are recommended (April, July and October). In small-scale plantations of plantains, nematicides are not recommended because of their high toxicity, hazards to humans and animals and their high cost.

Botanical nematicides and biological control

Studies have been initiated on the efficacy of neem (*Azadirachta indica*), *Chromoleana odorata* and *Thitonia diversiflora* against nematodes. Collection of indigenous strains of arbuscular mycorrhizal fungi (AMF) from Cameroon to set up *in vivo* cultures for

future studies on their possible effect to alleviate nematode constraints in banana plantations have also been initiated. Preliminary results of the survey indicates that more than 50% of roots collected in banana fields are mycorrhized (Fogain and Ngamo 1998). Trap pot cultures using leek seedlings have been set up with soil samples collected from these areas to isolate strains.

Plant resistance

As most small-scale farmers do not apply IPM strategies, host plant resistance will certainly bring them substantial benefit from little investment. Since 1989, more than 200 accessions from different genomic groups have been screened at CRBP to look for sources of resistance and for plantains with low susceptibility to *R. similis*. Results indicated that all the plantains and Cavendish are susceptible to nematodes (Fogain 1988b). Yangambi Km5 and other clones of the Ibota subgroup and a clone of the Pisang Jari Buaya subgroup are resistant to *R. similis*. Selangor, Calcutta 4 and most *Musa balbisiana* are significantly less susceptible than Cavendish, plantains and East African banana. Some of these resistant or tolerant clones are already being used in breeding programmes for resistance to black Sigatoka.

Sigatoka diseases

Distribution and importance

Two species of Sigatoka are present in Cameroon: *M. musicola* causing yellow Sigatoka and *M. fijiensis* causing black Sigatoka. These diseases are among the major constraints to banana and plantain production in Cameroon. Yield loss varies between 50 and 100% (Mouliom Pefoura and Fouré 1988). *M. fijiensis* was reported in commercial banana plantations in 1983 (Mouliom Pefoura 1984). Due to its high level of pathogenicity, it is progressively replacing *M. musicola* in areas situated at lower elevations where the latter has existed for almost half a century. The disappearance process of *M. musicola* often happens after a period of coexistence with *M. fijiensis* (Mourichon and Fullerton 1990). In lowland areas, *M. fijiensis* is known to cause severe damage to cultivars which are less susceptible to *M. musicola*. *M. musicola* is more common at high altitudes with severe damage inflicted on certain *Musa* subgroups such as plantains (AAB) which has been reported less susceptible at lower elevation (Fouré and Lescot 1988). Similar distribution of the two species has been reported in the coffee production zones of Colombia and Costa Rica (Martinez Figueroa 1989, Avila Adame 1991, Tapia Fernandez 1993). In Cameroon both species now exist in mixtures in the Centre, West, Littoral and South-West provinces, whereas *M. musicola* is the only species encountered in the North-West and *M. fijiensis* in the East and South provinces (Fig. 1). High infection levels are found in most of the provinces except in the West. Lower levels of damage were found to be due to low plant density and unfavourable climatic conditions.

Integrated management of *Mycosphaerella* spp.

Several control measures are recommended to smallholders. However, because resource-poor farmers lack income, *Mycosphaerella* disease IPM in Cameroon is only applied in commercial banana plantations. In these large-scale plantations, black Sigatoka is controlled primarily by fungicides, because non-chemical alternatives do not provide commercially acceptable control. Smallholders usually apply cultural practices to reduce inoculum in the field.

Cultural practices

Good agronomic practices including improved drainage, good weed control, desuckering and proper spacing are all important in reducing the spread of infection through the reduction of humidity within the plantation. Proper fertilization is also important. Current studies undertaken in coffee areas in Colombia seem to show a positive influence of proper plant nutrition on tolerance to this disease.

Planting date has been shown to reduce the disease incidence on plantain. For instance, disease incidence is reduced when planting bananas and plantains in Njombé takes place between June and October compared to the period from November to May.

Leaf pruning of highly diseased and dry leaves reduces the inoculum pressure in the plantation. The upper face of leaves must be placed on the ground. This technique is largely applied by farmers, but it is not effective during the period of high disease pressure (wet season). Current studies are focused on the impact of regular leaf pruning on disease.

Chemical control

In commercial banana plantations, black Sigatoka disease is controlled by repeated applications of fungicides. In small plantations, efficacy of chemical control has been demonstrated by applying minimum fungicide amount with knacksap sprayers combined with leaf pruning (Mouliom Pefoura and Fouré 1988). Nevertheless, financial cost of this practice did not allow adoption of this method by farmers.

Three fungicide chemical groups having different mode of action are used: triazoles (systemic IBS fungicides, e.g. active/commercial product propiconazole/Tilt), benzimidazoles (systemic antimitotic fungicides, e.g. active/commercial product benomyl/Benlate), morpholines (penetrating product, e.g. active/commercial product tridemorph/Calixin). The choice of fungicides in an alternating scheme takes into account the registered active ingredients available locally, the parasite pressure and the structure of the pathogen population (resistance). Until 1997, the proposed fungicide application scheme in Cameroon was as follow: the alternate use of benzimidazole and morpholine during the dry season and the use of a cycle of three successive triazoles and two successive benzimidazoles during the wet season. Due to the recent appearance of cases of field resistance to benzimidazoles and triazoles, this rotation of fungicides is being modified by the use of a new compound with a novel mode of action and belonging to the b-methoxyacrylate group.

To reduce the annual number of fungicide applications, a successful forecasting system has been developed to control black Sigatoka disease in Cameroon (Mouliom Pefoura and Lassoudière 1984, Fouré 1988). This forecasting system is based on the state of disease evolution (SE) corresponding to a quantitative evaluation of symptoms on the leaves. The disease incidence is recorded once a week and fungicide application is only carried out when SE increases successively twice. This biological forecasting method has been used with success between 1984 and 1996, allowing disease control with about 20 applications instead of more than 30. It requires the use of systemic fungicides and good logistic organisation to be effective. Because of current logistic problems banana plantations apply fungicides on a temporary basis (every 10-14 days). Studies have been undertaken to improve the biological forecasting system.

- (i) Detection prior to symptom development has been tested with an immunological method (ELISA) that allows application of the fungicide at an early stage in the reproduction cycle of the fungus, leading to a better efficacy and reduced fungicide applications.
- (ii) A bioclimatic forecasting system combining biological and climatic parameters has been tested to decide on the date of fungicide application. This system has been recently developed in Costa Rica and is currently used with success in plantain plantations (Lescot *et al.* 1998).

The monitoring of the sensitivity of strains to fungicides has been established at CRBP as the successive applications of a fungicide may induce the selection of resistant strains of *M. fijiensis*. *M. fijiensis* populations of the two large-scale banana plantations are monitored systematically twice a year. These population studies concern both benzimidazoles and triazoles. Since 1997, a decrease in sensitivity of strains to these fungicides was shown in the laboratory. The introduction in Cameroon of a new molecule belonging to a new chemical group (beta-methoxyacrylates) is one way to overcome this problem. It allows a reduction of the number of applications of triazoles and benzimidazoles.

Plant resistance

Cavendish varieties traded internationally and all known plantain landraces are susceptible to black Sigatoka disease. The development of Sigatoka disease resistance has been a major breeding objective in banana and plantain for many years. Indeed, on the one hand smallholders cannot afford expensive fungicide applications and on the other hand commercial plantations need to increase the durability and the efficacy of fungicides. Thus genetic improvement for black Sigatoka resistance is a major component of IPM especially in the traditional farming system. This genetic improvement programme includes the search for sources of resistance to black Sigatoka and creation of new varieties resistant or tolerant to the disease. Therefore, resistance to black Sigatoka is the top priority of the CRBP breeding programme. The screening of over fifty clones belonging to various genetic subgroups under natural infection conditions in Cameroon revealed the existence of phenotypes of highly resistance (HR) and partial resistance (PR) (Fouré *et al.* 1990). All clones of the Ibota subgroup (AAA)

and clones (AAw) of the subspecies *microcarpa* (Truncata), *malaccensis* (Pahang) and *burmanicoïdes* (Calcutta 4) have a HR phenotype. The PR phenotype is found in any genomic group. No HR clone was found in genomic group with a *balbisiana* gene. Results of this screening allowed definition of two strategies: (i) short-term strategy: screening for resistant cooking bananas. Some tolerant ABB clones such as Pelipita were already tested and accepted by the farmers. (ii) medium-term strategy: screening for resistant diploids used as male parent to improve plantain landraces (Tomekpé *et al.* 1995). Multilocational evaluation of the most promising tetraploid hybrids with black Sigatoka resistance is underway in farmer fields.

Conclusions

In Cameroon, only commercial banana growers have successfully adopted IPM. In this type of cropping system, cultural practices combined with pest and disease forecast are being used to reduce the number of agrochemical treatments. In small-scale farming systems, several constraints limit the implementation of IMP strategies:

- (i) lack of basic information on the pest or disease situation, on control measures and on new technologies available,
- (ii) lack of finance,
- (iii) area under cultivation too small.

To overcome this situation, (i) collaboration between researchers, extension workers, NGOs and farmers should be strengthened; (ii) on-farm training programmes should be organized to bring together all the players; and (iii) farmers should be encouraged to form cooperatives.

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Session 2E

Review of IPM research activities

**Farming systems
socioeconomics
and banana IPM**

Cultural practices in relation to integrated pest management in bananas

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Introduction

In the case of commercial banana production, chemical control measures still predominate in the elimination of biotic factors that limit or depress yields. In this group of factors, black Sigatoka, Panama disease, nematodes and the weevil borer are by far the most important. Resistance breeding remains a critically high priority, especially for controlling black Sigatoka and *Fusarium oxysporum* f. sp. *cubense* (race 4), but such resistant material is not yet available for the Cavendish group of cultivars which form the basis of world trade in bananas. For these commercial growers who apply chemicals, cultural practices play only a minor role in the context of integrated pest management (IPM).

In terms of world production, bananas are essentially a smallholder crop in which food security and a localized cash economy are the main considerations. In common with commercial banana production, breeding for resistance to pests and diseases is also critically important for small-scale rural farmers, but is even more so in this sector due to the high cost and inaccessibility of chemicals and the fact that bananas and plantains form the staple food of these people. Therefore, cultural practices are the only measures available to small-scale farmers for the control of pests and diseases. The focus of this paper therefore lies with the latter group of farmers, in relation to cultural practices and IPM.

Smallholder cultivation of *Musa* in sub-Saharan Africa

In sub-Saharan Africa (SSA), *Musa* provides more than 25% of the carbohydrate requirements for about 70 million people. Bananas and plantains are an integral component of most farming systems where the emphasis is on food security for the rural

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population. In fact, in Uganda, the per capita consumption of *Musa* is in the excess of 250 kg/year (Karamura 1992).

From 1970 to 1997, cooking banana yields fell from 8 t/ha to 5 t/ha in Uganda and from 11 t/ha to 5 t/ha in Rwanda. Yield decline in new plantations is very rapid and can often be seen within two years, i.e. in the first ratoon cycle. There are many reasons for this yield decline, the most important of which are black Sigatoka, *Fusarium oxysporum* f.sp. *cubense*, weevil borer, nematodes, poor planting material, declining soil fertility and shorter fallow periods. These factors are invariably interrelated in that infected plant material causes more rapid plant decline, which necessitates more frequent replanting, which means shorter fallow periods, which in turn enhances the decline of soil fertility, especially as no inorganic fertilizers are applied. The establishment of "clean" planting material in "clean" soil would reverse this negative spiral. However, because the important role of *Musa* in food security is not fully recognized, research tends to be underfunded and the technology needs of the smallholder are not being addressed. Thus progressive yield decline remains a severe problem.

Cultural practices in relation to IPM in banana

Assuming this paper concentrates on soil pests and diseases, there are four main areas of influence on which to focus:

- a. reducing pest numbers in the soil before planting,
- b. reducing pest numbers in the planting material before planting,
- c. promoting root health and vigour in the plantation to help the plant cope with pest pressure, and
- d. reducing the chances of pest entry into the rhizome or roots.

Reducing pest numbers in the soil before planting

Use of clean virgin soil

This is the ideal scenario but such soil is becoming less and less available due to a history of shifting cultivation using infected planting material in new soil. If there is clean virgin soil still available then it is absolutely essential that clean planting material is used to establish a banana plantation.

Fallow and rotation cropping

Since increasing population pressure is reducing the availability of agricultural land, fallow periods are becoming shorter after yield decline has necessitated plantation removal. A two-year fallow is more effective than a one-year fallow, but for however long it is, old rhizomes, suckers and other banana trash must be removed to starve out nematodes. Also, alternative host crops and weeds must be avoided for at least one year. Under bare fallow in Australia, no *R. similis* was recovered from old banana roots after 8 weeks burial, but *R. similis* survived for up to 6 months in old rhizome tissue (Stanton 1998). This emphasizes the need to remove old rhizome tissue when fallowing.

Currently, however, bare fallow is not recommended in Australia due to the risk of soil erosion which would also be a problem in any high rainfall area.

In crop rotation experiments, groundnuts and maize were shown to be hosts for *R. similis*, whereas cassava, potato and cocoyam were not (Price 1994). Banana crop rotations showed that the grasses *Panicum maximum* and *Phaseolus altopurpureus* hosted no *Radopholus similis* or *Meloidogyne javanica* after 32 weeks (Colbran 1964) and sugarcane eliminated *R. similis* after 10 weeks (Loos 1961). In recent work by Stanton (1998), it was determined that sorghum was a strong host for *R. similis* in banana rotation cropping whereas sugarcane and jarra grass were excellent at controlling this nematode. From all this work, it appears that certain crops can be recommended for banana rotations such as sugarcane, various grasses, cassava, potato and cocoyam. On the other hand, groundnuts, maize, and sorghum should be avoided by small-scale banana farmers as rotation crops for bananas.

Environmentally-friendly nematicides

Preplant fumigation with EDB or methylbromide is expensive and very toxic. It is being phased out in commercial plantations and is totally unsuitable for small-scale farmers. Likewise, the use of chemical nematicides in the planting hole is expensive, toxic to humans and damaging to the environment. In addition, they are subject to advanced microbial degradation and resistance buildup of the target organism, which reduce their effectiveness. On the other hand, research being conducted at many institutions is showing that environmentally-friendly products and fungal-based bionematicides can be used to effectively control nematodes. This development fits in better with the IPM concept but currently these products are expensive and not readily available for smallholders to purchase.

Reducing pest numbers in planting material before planting

Tissue culture planting material is totally free from injurious pathogens such as *Fusarium oxysporum*, nematodes and weevil borer. However, it is essential that this material should be used in conjunction with clean soil. If the soil is infected with any of these organisms, then tissue culture material should be avoided because the plants, although very vigorous, have no reserves to withstand severe root damage soon after planting. Suckers can survive better than tissue culture plants under infected soil conditions. However, if the soil is infected with disease, nematodes or weevil borer, higher yields can be expected if suckers are treated. The options for sucker treatment are as follows.

Paring

This involves slicing off the outer layers of the rhizome and inspecting the white tissue for infections or weevil tunnels. All discoloured rhizomes are then discarded and only clean ones are used for planting. The operation is fairly easy and inexpensive although it is not a guarantee that clean looking rhizomes are in fact uninfected.

Solarization

This involves heat treatment by solar radiation. In an experiment by Mbwana and Seshu Reddy (1995), banana suckers were treated in a homemade solarization tank and planted out. After 650 days of growth, roots were inspected and analyzed for numbers of the nematode *Pratylenchus goodeyi*. From unpared suckers there were 29767 *P. goodeyi* per 100 g roots compared with 5027 *P. goodeyi* from pared suckers. With suckers that were both pared and solarized, the count was only 542 *P. goodeyi* per 100 g root. This indicates the beneficial effect of combining two treatments and also shows that paring alone does not remove all nematode infections.

Hot water treatment

This can be used to destroy nematodes and weevil borer in rhizome tissue without damaging the rhizome. In a recent experiment by Hauser (1998) at IITA, plantain suckers were treated with hot water at 52°C for 20 minutes. Mat survival increased by 11% and plant lodging was reduced from 30% to 10% with this treatment. Yields in the plant crop also showed the interactive benefit of hot water treatment together with fertilizer use. Thus, for control (untreated), hot water-treated suckers, fertilized plots and hot water treatment together with fertilizer, plant crop yields were 10, 13, 15 and 21 t/ha, respectively. In the first ratoon, corresponding yields were 0.17, 3.06, 1.44 and 6.92 t/ha, respectively. The ratoon cycle also shows the interactive benefit of the two treatments but more importantly, it shows that severe yield decline occurred in all treatments by the second cycle, due to the rapid resurgence of pest numbers.

Treatment with neem

As an environmentally-friendly sucker treatment, the use of neem cake (*Azadirachta indica*) at 100 g per sucker at planting, then at 4 and 8 months after planting, reduced *Pratylenchus goodeyi*, *Meloidogyne javanica* and *Cosmopolites sordidus* to the same levels as with the use of Furadan nematicide. The percentage coefficient of infestation with weevils was reduced from 75% down to 5% (Musabyimana 1998).

Promoting root health and vigour in the plantation to counteract pest infestations

Various cultural aspects of *Musa* production can be used to increase root vigour, depth of rooting, survival potential and productivity of banana plants being established in infected soil. For resource-limited, small-scale farmers, some of these measures are possible whereas others are only achieved by costly management inputs.

Soil preparation

It has been widely demonstrated that a soft, easily worked soil, encourages more and longer roots in the root zone than a hard, compact soil. In a survey in Martinique, Delvaux (1995) found that as soil bulk density decreased from 1.2 to 0.6 g/cm³ so banana root density increased from 1 to 7 roots/dm². He also found that certain soil types such as andisols were much less prone to compaction over time than vertisols or ferrisols.

Planting deeply in furrows or basins also encourages a deeper root profile than surface planting. It is logical that a denser and deeper root system would be able to cope better with infections from nematodes than a weak, superficial root system, and in addition, reduce the number of fallen pseudostems.

Inherent vigour of tissue culture planting material

In a comprehensive study by Eckstein and Robinson (1995), tissue culture planting material was compared physiologically with conventional suckers. For 4 months after planting, the tissue culture plants exhibited a higher rate of photosynthesis than sucker leaves. This physiological boost caused total root dry matter of the tissue culture plants to be double that of the sucker root system 4 months after planting and total plant dry matter to be double that of suckers by 5 months after planting. Once again it is emphasized that these differences are only achieved with optimum management and with no biotic constraints whatsoever.

Boosting tissue culture nursery growth with microorganisms

The enhancement of plant and root growth of young tissue culture banana plants was studied by Severn-Ellis (1998) using non-symbiotic bacteria. It was found that plant growth, dry mass and leaf area were significantly improved by a combination of *Bacillus* bacteria and fertilizer. Bacteria alone were less effective than fertilizer alone, but the strong interaction between the two showed that bacteria could play a major role in the presence of plant nutrients, probably by enhancing the availability and uptake of these nutrients. Progress has also been made in the field of using fungal endophytes for the biological control of nematodes. Niere *et al.* (this volume¹) found that when various fungal isolates were inoculated into 19-week-old tissue culture banana plants, the rate of multiplication of *R. similis* in root segments of these plants was reduced by more than half, compared with non-inoculated plants. Plant height of the inoculated plants was also increased. These techniques may eventually play a role in protecting the root environment in smallholder banana plots.

Supplementary fertilizers

Declining soil fertility is one of the major causes of banana yield decline with smallholders. Many experiments have been conducted to show the beneficial effect of fertilizers on yield. An important finding in all this work is the strong positive interaction of fertilizer use with other inputs like hot water treatments, microorganisms in the tissue culture medium, organic amendments and mulch, on boosting root vigour and yield.

Organic amendments

Manure helps to reduce the level of nematodes in the long term but large amounts are required for direct nematicidal properties. Secondary effects result from increasing root vigour to cope better with nematodes. Chicken litter can also reduce nematode populations. The high nitrogen seems to inhibit nematodes but stimulates microflora which indirectly reduces nematodes.

¹Niere B.I., P.R. Speijer and R.A. Sikora. Fungal endophytes for the biological control of *Radopholus similis*.

Mulching

There are many advantages of mulching in bananas which can all play a role in promoting root health and vigour in the plantation. These are:

- a. increasing and replenishing soil organic matter,
- b. reducing surface temperature and temperature fluctuations,
- c. reducing weed growth,
- d. improving soil structure and water infiltration,
- e. decreasing soil erosion by wind (less dust),
- f. decreasing soil erosion by water (less runoff),
- g. reduced soil compaction,
- h. decreased water loss via surface evaporation, and
- i. roots forage higher and grow more vigorously.

Mulching is essential in dryland banana farming and especially on resource-limited plots. In West Africa, Wilson (1987) found that cumulative plantain yield on mulched plots was fourfold higher than that on clean cultivated plots. In Brazil, Cintra and Borges (1988) found that organic mulch on bananas gave an average yield threefold higher than that on hand weeding or cover crop plots. In West Africa, Swennen (1990) increased plant crop plantain yield from 0.6 to 11.9 to 14.1 and to 18.8 t/ha for control, fertilized, mulched and fertilizer plus mulch plots respectively. Mulch therefore played a more important role than fertilizer but the interaction of mulch with fertilizer was the ideal. In the ratoon crop, yields dropped severely due to pest pressure, but the mulched plots still sustained a yield of 10 t/ha.

Reducing the chance of pathogens entering the rhizome or roots

These techniques mainly relate to plant infestation by the weevil borer, *Cosmopolites sordidus* Germar.

Trapping

Old pseudostems are cut into pieces and placed in the plantation to attract and trap adult weevils which should be regularly collected and destroyed.

Plant residue removal

This involves cutting of old pseudostems low down and chopping into small pieces for faster decomposition.

Sanitation

New suckers should not be left standing on the soil surface overnight before planting the next day.

Although these three practices can help reduce adult weevil populations, they are extremely labour-intensive operations.

Conclusions

- Cultural practices are invariably the only techniques a smallholder can use to control or live with soil pests and diseases in banana/plantain production.
- Much information is already available from experiments on smallholder plots, which relate cultural practices to increases of growth and yield under high pest pressure.
- In much of the experimental work, the inference that increased yields are due to either increased root vigour or lower pest numbers, is often speculative.
- More quantitative studies are required to relate cultural techniques to specific root measurements and/or pest counts. In this way the mode of action of these treatments would be better understood.
- There is a widespread need for better transfer of new technologies to the small-scale farmers via training, demonstration plots and participatory techniques.

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Understanding current banana production with special reference to integrated pest management in southwestern Uganda

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Background

Globally, bananas are the fourth most important food crop after rice, wheat and maize. In the Great Lakes Regions of East/Central Africa, they are the most important food staples. For Uganda, bananas are of strategic importance to food security. For example, 75% of farmers allocate 40% of cropped land to banana production, mostly for home consumption. However, productivity is decreasing due to three mutually reinforcing factors, namely (i) pests and diseases, (ii) declining soil fertility (Gold *et al.* 1993) and (iii) socioeconomic factors such as labour, infrastructure and marketing problems (Karamura 1993). There is also a high regional variability in the net impact of these constraints. For example, whereas, between 1970 and 1990, banana production declined substantially in the eastern and central traditional mainstay producer regions, it expanded appreciably in the southwestern region. In the eastern and central regions, exotic beer banana cultivars and annual crops such as cassava, maize and sweet potatoes have replaced cooking bananas (Gold *et al.* 1993). In response to these trends and constraints, a series of measures were taken, including the development of a research agenda by a consortium of international and national research institutions, namely the Uganda National Banana Research Programme of the Uganda National Agricultural Research Organisation (NARO), the International Institute of Tropical Agriculture (IITA), and the African Highland Initiative. In 1997 the collaboration was extended to the International Centre of Insect Physiology and Ecology (ICIPE) to provide an input in farmer-participatory research with special reference to IPM.

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