Integrated Pest Management Approaches Developed in the French West Indies to Reduce Pesticide Use in Banana Production Systems

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Abstract

The monoculture of banana can have a serious detrimental impact on the environment as pesticide treatments can lead to surface and groundwater pollution. Different approaches based on IPM (integrated pest management) have been developed in the French West Indies to reduce the use of the pesticides in banana cultivation. These methods have been developed using management techniques that prevent the build-up of banana pathogens and also eliminate them, non-chemical techniques, such as cultural practices and biological control, and resistant cultivars. As a result, new crop management systems have led to a 65% decrease of pesticide use over the last 10 years. Major results of the research already undertaken and future research that is being considered to reduce pesticide use in banana plantations are reviewed.

INTRODUCTION

Dessert bananas grown for export, which amount to 16 million tonnes per year, form a large part of agricultural production in some tropical countries. They are usually cultivated in an intensive monoculture sustained by the application of large quantities of fertilisers and pesticides. The few cultivars used for production are susceptible to numerous pests and diseases. Genetic improvement is difficult, and resistant commercial export cultivars are not yet available. The present production system has a strong negative environmental impact, leading to reduced soil fertility, proliferation of soil pests, soil structure degradation, damage to the organic quality of the soil and the reduction of biodiversity. Increasingly strict regulations for pesticide use and the respect of 'good farming practices' are decided at public-authority level in Europe or imposed by retail chains anxious to meet consumer expectations. The development of new, less polluting cropping systems has become a major issue for producer countries and consumers. Recent results of work undertaken into the non-chemical control of banana pests and diseases in the French West Indies (FWI) are reported here.

IMPROVEMENTS TO NEMATODE CONTROL

Banana nematodes are frequently present in the roots in mixed species communities (Cofcewicz et al., 2005; Risède et al., 2004). Their overall effect on the crop results from interactions between the cropping system and environmental conditions (soil type, climate). Banana nematodes can cause production losses of more than 50% (Chabrier et al., 2005a; Gowen et al., 2005). Traditional control methods have long been based on the use of chemical nematocides, especially organophosphates and carbamates. Most of these substances are classified as toxic or highly toxic and are increasingly abandoned in favour of alternative methods that have a lower negative impact on human health and the environment.

In the mid-1980s, the precepts of preventive control “healthy plant material (from in vitro culture) in a healthy soil (obtained through rotation or fallow)” have been formulated. In the past decade, research has optimised cultural control through the rational use of nematode cleansing fallows and providing decision tools, such as biological tests to evaluate the quality of nematode cleansing in fallows, the occurrence of nematodes in tissue-culture plant nurseries or in the field (Chabrier and Quénéhervé, 2003). In addition, Cavendish (AAA genome) clones less susceptible to nematodes have been tested and validated. Based on the results of research, banana producers in the FWI have adopted the use of fallow and the practice of rotating banana with crops, such as pineapple or sugar cane, to control nematode infestations (Chabrier et al., 2005b). The adoption of these control methods has been more of a necessity because of French and European phytosanitary legislation, which has restricted the use of a number of registered nematocides. As a result, use of nematocides has decreased by more than 60% in the last 10 years (Chabrier and Quénéhervé, 2001; Chabrier et al., 2005b; Fig. 1).

Several innovations for cropping systems in the West Indies are ready for testing and incorporation in the crop management sequences already developed: new hybrid bananas that are resistant or tolerant to banana nematodes, and cover crops that are non-hosts for nematodes and that may be used in crop rotations or in association with banana (Quénéhervé et al., 2002). Ongoing research efforts include the identification of nematotoxic cover plants, the design of sustainable strategies for the use of banana hybrids resistant to nematodes and understanding the links between biological diversity in soils and the sustainability of cropping systems.

IMPROVEMENTS TO THE CONTROL OF MYCOSPHAERELLA LEAF SPOTS

Mycosphaerella leaf spot diseases are considered the most serious foliar diseases of banana and a major production constraint for dessert banana exports. Dessert banana production in the FWI - like everywhere else in the world - is based exclusively on banana cultivars in the Cavendish subgroup that are very susceptible to leaf spots. Control is essential if fruit is to be exported.

FWI banana plants are currently affected by Sigatoka leaf spot and are threatened by the introduction of black leaf streak, which is spreading in the Caribbean region. Currently, the only commercial control method is the frequent aerial spraying of fungicides. However, fungicides are harmful to the environment, and the causal fungi have an evolutionary potential to develop resistance against fungicides (de Lapeyre de Bellaire, 1990; de Lapeyre de Bellaire et al., 2009).

A reduction in fungicide usage for leaf spot control is a priority in the FWI because of the withdrawal of certain fungicides, the human health concerns of the local population and tourist industry, and the expected ban on aerial spraying in the near future.

Use of a Disease Forecasting System

The forecasting system is aimed at reducing the number of fungicide sprays per year while still achieving effective control of the diseases. This reduces the production costs, the pollutant load and the risk of appearance of resistance. The system is based on the use of mineral oil, which has a fungistatic effect, and a mixture of systemic fungicides (of five different chemical families). The treatment must be applied to an entire production area as leaf spot diseases are spread by wind (Ganry and Laville, 1983).

Forecasting systems perfected at the beginning of the 1970s for Sigatoka leaf spot (Ganry and Laville, 1983) and in the 1980s for black leaf streak (Fouré, 1988) have considerably reduced the number of fungicide spray applications per year, and thus production costs. Without a forecasting system, 25 and 50 sprays per year are required to control Sigatoka leaf spot and black leaf streak, respectively. Using the forecasting systems, spray applications to control Sigatoka leaf spot in the FWI has been reduced by 75%, which is amongst the lowest application rate in the world, and spray applications to control black leaf streak in Cameroon have been reduced by more than 60% (de Lapeyre de Bellaire et al., 2009). Forecasting systems considerably reduce the environmental impact of chemical control of leaf spot diseases. Without a forecasting system for Sigatoka leaf spot, the quantities of active substance per hectare per year would amount to 20 to 40 kg compared to 0.7 to 1,5 kg with a forecasting system.

The use of forecasting systems may also slow the appearance of populations with resistance to certain systemic fungicides (Ganry and Laville, 1983). In the FWI, the forecasting system has been used to control Sigatoka leaf spot disease successfully for over 30 years, with an average of 6-8 fungicide spray applications sprays per year. In Cameroon where a forecasting system has been used, fungicide resistance to triazoles appeared in *M. fijiensis* populations only after more than 15 years as compared to 5-8 years in Latin America. The emergence of resistant strains in the conditions of Cameroon was due to insufficient logistics for spraying operations. With adequate disease management, fungicide resistance would probably have not emerged.

Research is now in progress on perfecting a new forecasting system using meteorological parameters that could trigger preventive treatments.

Resistant Cultivars

The use of banana cultivars with resistance to leaf spots is considered to be the most durable control method. A CIRAD breeding and selection programme was begun in the 1980s to produce dessert banana hybrids with resistance to leaf spot diseases. New cultivars developed are currently under evaluation. Large-scale cultivation of leaf spot-resistant banana cultivars will have several impacts. It will lead to a drastic reduction in fungicide spray applications and will also reduce the overall inoculum pressure in fields of susceptible cultivars grown in the same production area.

Knowledge of the fungal population structures and banana-pathogen interactions has also increased over the last 10 years (Rivas et al., 2004; Abadie et al., 2003). This helps in the choice of parents for breeding and has allowed the development of early tests for susceptibility to leaf spots. Strategies for the use of these new cultivars are now being tested.

IMPROVEMENTS IN THE CONTROL OF BANANA WEEVIL

Chemicals have historically been used to control the banana weevil (*Cosmopolites sordidus*). Highly toxic insecticides used earlier included organochlorides (chlordecone), organophosphorus insecticides and phenylpyrazole (Chabrier et al., 2005a). Past use of the persistent chlordecone has resulted in serious soil and water pollution problems today. The four groups of insecticides used worldwide today are nicotinoids, phenyl-pyrazol, carbamates and organophosphorus compounds. These are often toxic for humans and other non-target organisms.

In the FWI, a ban on cadusafos is planned, leaving Nemathorin® 10G, (which is primarily a nematocide and its insecticidal effect is a secondary feature (Chabrier et al., 2002)) as the only permitted product. In Martinique, the use of products has decreased over a 10-year period (1996 to 2006) from 130 tonnes to zero for insecticides only, and from 580 to 162 tonnes for combined insecticide/nematocide products, with no significant decrease in yields (Fig. 1). These results can be ascribed at least partly to the new cultural practices and control methods.

Pheromone Traps

The first traps using sordidines (aggregate pheromones of *C. sordidus*) were designed by Chemtica in 1997 (Alpizar et al., 1998). A study programme was launched to evaluate their efficiency as a mass-trapping tool and as a population indicator. Although mass trapping can be effective in slowing down infestation, when infestation is strong, traps only capture that part of the population that moves, which may be less than half of the total population. Many growers in heavily infested areas in Guadeloupe and Martinique have observed that when a plantation is destroyed using mechanical means, the number of weevils captured increases three to five-fold, indicating that this proportion of the *C. sordidus* population remained sedentary when the banana plants were standing. In other words, the attraction of the banana plants competes with that of the traps. This control method also requires regular checks on the lure and good plantation management, as weed growth reduces trapping effectiveness and weevil incidence is greater on slow-growing plants. Mass trapping is less effective in controlling *C. sordidus* in the long term. Therefore, trapping should be complemented by the use of other methods.

Monitoring traps has helped to show how weevil populations behave in fallow fields after plants have been treated with glyphosate. Glyphosate destroys the burrowing nematode *Radopholus similis* effectively, but not *C. sordidus* (CIRAD, unpublished data). Numerous adults shelter in the corms of dead banana plants. When this material is destroyed mechanically, traps capture large numbers of weevils. This can be explained by the fact that, after the destruction of their habitat, practically all the adult weevils become mobile. Keeping traps in fallow fields would thus seem beneficial in reducing pest pressure. Mobile weevils would be destroyed instead of infesting neighbouring banana plantations.

Ongoing research efforts include studies of spatial arrangements of the cultures to reduce weevil development and to improve the efficiency of trapping.

Biological Control

The French National Institute for Agricultural Research (INRA) in Guadeloupe has bred entomopathogenic nematode strains that effectively control *C. sordidus* in the laboratory. In the field, the results were disappointing, because the nematodes are susceptible to nematocides and spread poorly. Sordidine traps can be used to attract weevils into a confined, limited space for inoculation by an entomopathogen rather than killing them. The trapped specimens can then be used as spreading agents. Pheromone traps to which entomopathogenic nematodes (*Steinernema carpocapsae*) were added weekly gave good results in Martinique in two series of trials in areas where pest pressure was particularly strong, on the condition that the general state of the plantations was good (Chabrier et al., 2002). Research to improve biological control methods is ongoing.

Prevention by Field Maintenance

To eliminate food and shelter for the weevil, corms and pseudostems of fallen or dead plants must be cut into sections and then split lengthwise to favour rapid decomposition. Mechanical destruction of the corms is necessary after chemical destruction of plants when fallows are initiated. Rotary spading machines break up dead corms much better than disc harrows. Field drainage should be installed as moist ground enhances the weevil development. Weeds should be controlled and the crop suitably fertilised to promote a vigorous crop.

IMPROVEMENTS IN THE CONTROL OF POST-HARVEST DISEASES

Two forms of anthracnose, both caused by *Colletotrichum musae,* produce storage diseases. Ripe-fruit (quiescent) anthracnose results in brown lesions on ripe fruits after they have left the ripening facility and rarely leads to commercial sanctions. Wound (non-quiescent) anthracnose results in large brown lesions on fingers damaged during harvesting or packing. The symptoms can be seen when the fruits are unpacked after sea transport, and serious commercial sanctions are applied (Jones, 2000).

Crown rot is another important disease. Here, a larger number of fungi, such as *C. musae*, *Fusarium* spp., *Verticillium* spp. and *Botryodiplodia*, are involved. The fungi spread from the cut surfaces resulting from dehanding at packing stations. Damage can be observed after sea transport, and this has serious commercial implications (Jones, 2000).

The fungi that cause post-harvest diseases are widespread in banana plantations. In the case of anthracnose, contamination by *C. musae* takes place mostly during the 1st month of flowering (de Lapeyre de Bellaire and Mourichon, 1997). Spores are spread by water and develop on banana material that is beginning to decompose, such as old leaves, bracts and especially flowers (de Lapeyre de Bellaire et al., 2000). Control of infections must start in the field at the time the inflorescence emerges from the top of the pseudostem and continue through to the packing shed. Bunches can be contaminated by crown rot fungi at different stages of development, which complicates the implementation of control methods. However, washing banana clusters in contaminated water is probably the main cause of infection.

Post-harvest fungicide applications do not always give satisfactory control. It can be ineffective depending on the production zone and the time of the year (Chillet et al., 2000). In addition, resistance to fungicides has developed in the various fungi involved (de Lapeyre de Bellaire and Dubois, 1997). Furthermore, chemical treatments can lead to chemical residues in fruit, and the safe disposal of the fungicide preparations used in the packing stations is problematic. Interest in the development of other methods is thus growing.

Cultural Practices to Control Anthracnose

The work carried out in the FWI has shown that the use of the cultural practices alone enables anthracnose to be satisfactorily controlled. These practices involve the removal of dried flowers in the field combined with sanitary deleafing (de Lapeyre de Bellaire et al., 2000), early bunch bagging, harvesting bunches at an optimal development time (Mouen Bedimo et al., 2003), the use of good harvesting (Chillet et al., 2006) and packing practices aimed at limiting wounds and bruising, and the implementation of good sanitary practices in packing stations. The implementation of these control methods is more effective when the fruit, such as that grown in mountain areas, has low susceptibility to anthracnose (Chillet et al., 2007). This strategy makes it possible to export fruit from certain geographical locations without any chemical treatment (de Lapeyre de Bellaire et al., 2005).

Modified and Controlled Atmospheres to Control Crown Rot

Non-perforated plastic packaging makes it possible to create a modified atmosphere that is poor in O_2 and enriched in CO_2. This type of packaging has clear advantages over perforated or pre-cut packaging. It improves fruit keeping as long as the cutting date is correctly timed. In addition, it limits the development of crown rot without fungicide application. A reduction of 60 to 80% in crown rot at the green fruit stage was observed in export trials using 20 µm and 50 µm non-perforated bags in comparison with fruits packed in pre-cut bags (de Lapeyre de Bellaire et al., 2005). However, the beneficial effect of this packaging diminishes during ripening, especially for 50 µm film. The transport of fruit in controlled atmosphere enables an equivalent control of crown rot to that achieved with modified atmosphere. This system has advantages for ripeners as the packaging is perforated and does not have to be torn open before gassing. However, transport in controlled atmosphere alone does not provide commercially acceptable control in all situations after ripening. In addition, controlled atmosphere requires substantial changes in sea transport. Fruit would need to be in the hold and not in containers, and oxygen extraction systems would have to be installed.

Biofungicides to Control Crown Rot

Different essential oils have been evaluated for crown rot control, but none have provided effective control. They were also found to be extremely phytotoxic. A preparation of organic acids (lactic acid, citric acid, ascorbic acid, palmitic acid), glucose, mannose and tocopherols enabled the partial control of crown rot during controlled inoculation tests. Partial biocontrol of crown rot has also been achieved through the use of a yeast, *Pichia anomala* strain O (Lassois et al., 2008), and further improvement of this biocontrol is in progress. Methods that give better results remain to be developed, but these will certainly have to be combined with shipment in modified or controlled atmospheres.

CONCLUSIONS

The alternative control techniques developed by the research sector and by producers to control banana pathogens and pests, and increasingly restrictive regulations on agricultural chemical use in Europe have driven research that has led to a drastic reduction of the use of pesticides in Guadeloupe and Martinique in the last 10 years. Continuing this progress is essential for ensuring crop sustainability. The challenge is to develop production techniques that minimise chemical pollution and also maintain the economic viability of the banana industry. The next priority is the adoption of banana cultivars resistant to Mycosphaerella leaf spots, so that fungicide spray applications become unnecessary. A major challenge is the selection/development of new resistant cultivars which tolerate long-distance post-harvest handling while also being acceptable to consumers. The development of improved banana weevil control techniques is also a major issue for the future.

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Figures

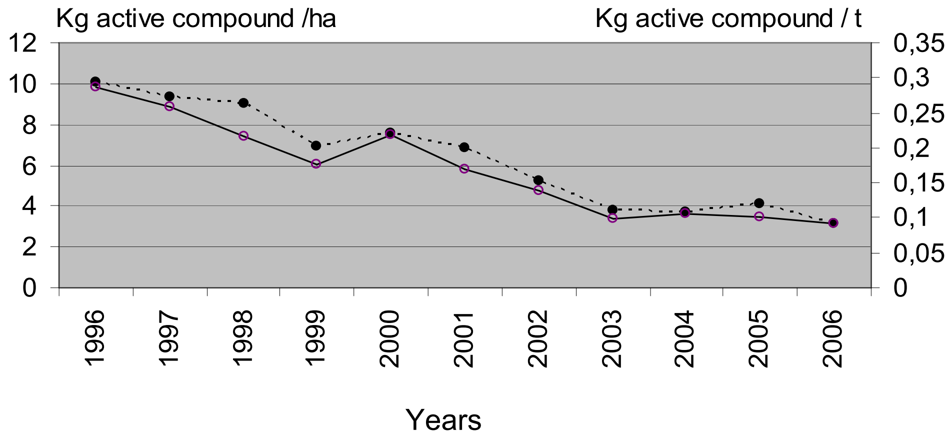

Fig. 1. Reduction in the use of nematocides and insecticides in Guadeloupe and Martinique banana production in the last 10 years expressed by cultivated area (○) or production level (●).