agement strategies are poorly developed and banana farmers in Uganda have no clear control options available. This project, which began in November 1999, is led by the Natural Resources Institute (NRI) in collaboration with the National Agricultural Research Organization in Uganda (NARO), the University of Reading and the International Institute for Tropical Agriculture (IITA) in Ibadan. It aims to gain a better understanding of the epidemiology and ecology of BSV, and its importance and effect on banana production in Uganda. The information generated will be used to provide recommendations on optimum crop and pest management practices to limit the spread of BSV and reduce its effect on crop productivity.

Many of the activities in the project will be conducted in selected 'benchmark' sites where related studies on constraints to banana production are being carried out with groups of participating farmers. One such activity is an examination of the main factors influencing the activation of the virus, the expression of disease symptoms and the damage caused to the plant. The interaction of the virus with the host plant is complex; symptoms can be very variable, often being similar to symptoms of nutrient or water stress, and there can be periods of symptom remission. Most, if not all, *Musa* species and varieties tested to date have BSV-like sequences integrated into their genomes, which cause no symptoms in the host. However, it is suspected that some of the integrated forms can be activated under certain conditions. This may be influenced by climatic factors, plant nutrient status, and crop management. For example, water stress and cool temperatures are suspected to be the cause of localized outbreaks of BSV.

Spread of BSV will be examined through field experiments at the benchmark sites to monitor the natural spread of BSV in blocks of 'trap plants' of virus-indexed Cavendish 'Williams'. The experimental plots will be monitored visually for symptom expression and by enzyme-linked immunosorbent assay for the presence of BSV. In a related study, researchers at the John Innes Institute, UK are investigating the possibility that BSV is present in different strains in Uganda.

The role of insect vectors in the spread of the virus in the field is being assessed. BSV is a badnavirus, most of which occur in clonally-propagated tropical crops. In natural systems, the most important means of spread for badnaviruses is probably by vegetative propagation, but transmission by mealybug vectors has been demonstrated. Indeed BSV has been transmitted to banana under experimental conditions by three species, although not by African mealybugs nor in the field. An identification key to banana mealybugs is being developed by Jerome Kubiriba (NARO) and Gillian Watson (CABI Bioscience).

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Forecasting Less Fungicide for Sigatoka Disease in Guadeloupe

Yellow Sigatoka disease caused by *Mycosphaerella musicola* (anamorph *Pseudocercospora musae*) is one of the most important threats the banana industry has to face in Guadeloupe. The disease causes leaf spot, and heavy attacks can reduce considerably the number of leaves and, ultimately, bunch weight. Nevertheless the most important effect of this disease is indirect. Heavy spotting results in a reduction in the greenlife of the fruit, which considerably depreciates its export marketability. At least ten viable leaves at harvest are necessary for good fruit marketability and therefore excellent control of this disease is essential.

From 1937, when yellow Sigatoka disease was first reported in Guadeloupe, 40-50 fungicide treatments per year have been used to control the disease, and treatments have been applied systematically according to a pre-established 'calendar' programme. The main objective of CIRAD-FLHOR (Centre de Coopération Internationale en Recherche Agronomique pour le Développement – Département Productions Fruitières et Horticoles) (ex-IFAC, ex-IRFA) research has been to reduce the number of treatments to the minimum necessary for ensuring good fruit quality, so decreasing the cost of control, as well as minimizing risks of fungicide resistance and environmental effects. Key to this was gaining a better knowledge of the disease, so that a forecasting system could be developed for optimizing fungicide applications.

Disease Epidemiology and Disease Control

Germination and stomatal penetration by the fungal agent of Sigatoka disease are impeded by fungal antagonism in old leaves. Stomatal penetration only occurs on the unfurled leaf (cigar) or on the first full leaf (leaf 1). Bananas produce new leaves at a rate of about one per week. Under climatic conditions most favourable to disease development, first symptoms are observed after 12 days on leaf 2. In less favourable conditions, the disease first appears on leaf 3 or older leaves, or not at all. There is a gradient of evolution of the disease from the top to the bottom of the banana tree, and fungicide applications should be aimed at the top of banana trees to control new infections.

The incubation period (from stomatal penetration to first symptom of disease) and the transition period (from stage 1 (minute yellow point) to stage 5 (necrotic grey spot), according to Brun's scale) vary widely with climatic conditions, and can be up to 100 days. Several steps of the disease cycle are highly dependent on the water status at the leaf surface. With such variability in the development of the disease, a forecasting system has real potential to reduce fungicide applications.

In the field, it is essential to control the disease before necrotic formation, as sporulation occurs in stages 4 (waterborne conidia) and 5 (airborne ascospores). Where leaves are heavily spotted they should be removed since they can produce ascospores for many months. Contact fungicides are not curative and are effective only before fungal penetration, so they are useless in forecasting strategies that rely on symptom observations. Systemic fungicides have a curative effect on streaks (stages 1, 2, 3), but not on necrotic lesions (stages 4, 5), although sporulation is temporarily decreased.

Area-wide control is important, as wind-transported ascospores can disseminate the disease over long distances, and failure of control in one area can affect neighbouring areas.

Four Keys to Successful Forecasting

The forecasting system relies on the timing of decisions and applications, treatment efficacy, and organization of control.

1. Decision Making. In Guadeloupe, both biological and climatic data recorded every week are used to decide on the application timing. The information they give is complementary. Climatic information is predictive and is useful in preventing spread of the disease. However, more importance is attributed to biological data, since they represent the real status of the disease. Comparison of theoretical and observed data is also essential to detect any disruption in the control strategy.

The biological forecasting system is based on early detection of new attacks by continuous monitoring. The stage of evolution of the disease (SED) is calculated as the product of the rate of new leaf production (foliar emission rate) and the speed of development of the disease. The speed of disease development is monitored continuously by inspecting the youngest five leaves on ten plants in a plot each week. The most advanced stage of the disease (according to Brun's scale) is scored for each leaf. A coefficient for each leaf number/disease stage association (which increases with disease severity and decreases with leaf age) has been calculated, and these are summed to provide an estimate of the speed of disease development. The foliar emission rate is an indicator of plant vigour, and the more vigorous the growth of the banana trees, the faster the disease develops.

SED is an indicator of the potential of development of the disease and graphic representation of its weekly value is used for decision timing. There is a threshold value for spraying, but attention is also paid to the slope of the graph of SED against time. Experience has also shown the level of SED up to which fungicide efficacy is maintained.

Climatic information identifies periods when conditions are not favourable to disease development. As thermal conditions are always favourable to disease development in Guadeloupe, temperature is not used for forecasting. On the other hand, Piche evaporation, assessed under an open-air station, represents well the water status at the leaf surface, taking into account global radiation, air saturation, wind and temperature. A relationship found between Piche evaporation and duration of treatment efficacy is used in decision timing.

2. Spray Timing. The time between decision and execution of one application should not exceed 7 days and the whole spraying area should be sprayed on the same day. Treatments are made by aeroplane, which facilitates a swift operation, but good logistics are essential. The climatic conditions required for aerial spraying are limiting, and the 'windows' are small: only in the early morning and late afternoon do thermal inversion and air turbulence not interfere with spray deposition. Aerial application is not possible at all on rainy and windy days. Miss a 'window' and control may break down.

3. Effective Treatment. This is dependent on the quality of the foliar application and good coverage is essential. Bad weather conditions on the day of application, irregular topography in the spray zone or the presence of obstacles can alter its uniformity. The use of mineral oil carriers has considerably improved the quality of coverage through aerial spraying with low volumes (at 12-15 litres/ha).

Efficacy relies also on a strong curative effect and systemic fungicides are thus preferred to contact fungicides. The systemic fungicides used for yellow Sigatoka control have an antimitotic mode of action or are ergosterol biosynthesis inhibitors of group 1 (DMI group) and 2. Oil carriers strengthen the curative effect because mineral oils have a fungistatic effect.

It is important to manage development of fungicide resistance, and alternation of groups of fungicides with different sites of action is essential. Regular monitoring of resistant strains using a methodology based on a germination test of conidia determines any changes in sensitivity.

Keeping the sources of inoculum at a very low level is also important. Chemical sprays do not eliminate the disease from spotted leaves, so where extensive spotting is present, new infections will develop quickly and the only solution is to remove leaves mechanically from the banana tree.

4. Organization. Since ascospores are transported by wind over long distances, the control strategy should be the same in all banana plantations. Organization is more efficient if centralized under a single technical service operating according to rational guidelines, rather than each grower implementing his own strategy, often with short-term objectives. Banana growers are grouped in an association that performs the control strategy. The cost of the phytosanitary campaign is covered by a tax on exported bananas.

Progress and Prospects

In Guadeloupe, the forecasting system has been operating for 25 years and consequently the control has been centralized over 6000-7000 ha of bananas. Disease assessment is done and meteorological records are recorded by a technical team from the banana growers association, and treatments are applied by the banana growers association or by a private company. An equilibrium of six treatments/year has been achieved since 1973 through a control strategy including timing of decisions and the use of a systemic fungicide in pure oil, compared with 10-20 treatments/year in other countries (Ecuador, Surinam, Dominican Republic, Jamaica, Windward Islands) where fungicides are applied on a calendar basis.

However, forecasting did not eliminate all problems. The exclusive use of benomyl from 1973-1982 led to the build-up of fungicide resistance. Fortunately, fungicides with novel modes of action were available at that time and their introduction in an alternation strategy enabled us to return to equilibrium.

Today, yellow Sigatoka disease is under effective control and is not affecting the quality of export fruit. The cost of control (0.08FF/kg) represents less than 3% of the production costs. The number of treatments and the quantity of pesticides discharged in the environment have been reduced 8-10 fold by the forecasting system. Nevertheless, we should not be complacent, for new fungicide resistance may develop. There is a need for more new fungicides with more novel modes of action, especially since antimitotic fungicide resistance is widespread in banana plantations. Products belonging to the strobilurin family are still under evaluation.

The problems faced by the banana industry are quite different to those for other crops, because only one group of cultivars (the Cavendish group) with low genetic variability is grown for export. A new approach to yellow Sigatoka disease control should combine genetic resistance or tolerance with a rational use of fungicides. It is vital to begin to look at these options because another important curse of bananas, black Sigatoka (or black leaf streak disease) (*Mycosphaerella fijiensis*), which is similar to yellow Sigatoka disease but more difficult to control, is now a serious threat for the Caribbean banana industry.

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Integrated Action against Nematodes in Uganda

Plant parasitic nematodes are a major constraint to sustainable *Musa* production. In Uganda, which is the world's largest producer of East African highland bananas (*Musa* spp., AAA group), nematodes have been identified as a major factor contributing to declining production. The major nematode species affecting banana in Uganda are *Radopholus similis* and *Helicotylenchus multicinctus* at an elevation of between 1000-1300 m above sea level. At higher elevations, the most common nematode species is *Pratylenchus goodeyi*. At Sendusu, near Kampala (1120 m), production losses in the commonly grown cultivar, Mbwazirume, from *R. similis* and *H. multicinctus* were 30-38% under a variety of management regimes. Damage is characterized by reduced flower production and bunch weight, and an increase in plant toppling because of poor root development.

Nematodes can be controlled with chemicals, but these may have adverse environmental effects and the use of nema-