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Varietal Reactions of Bananas and Plantains to Black Leaf Streak Disease *

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SIGATOKA diseases in bananas and plantains are caused by *Mycosphaerella musicola*, the agent of Yellow Sigatoka, and by *Mycosphaerella fijiensis*, the agent of Black Sigatoka or black leaf streak disease.

These two diseases are the most important diseases of banana, and may cause the total collapse of the plant, in highly susceptible varieties.

The initial symptoms are foliar leaf streaks, with consequent reduction in photosynthetic leaf surface. This results in a loss in gross yield at harvest time and also in the premature ripening of the fruit on the trunk, which prevents the marketing of the crop with a consequent net yield loss in exportable tonnage.

Mycosphaerella musicola (Yellow Sigatoka) attacks bananas but not plantains. However, *Mycosphaerella fijiensis* attacks both bananas and plantains. Plantains are a staple food in many West African countries. Black Sigatoka appeared only recently in Africa. It was identified in Gabon in 1980; the neighbouring countries (the Congo, Equatorial Guinea and Cameroon) are also now affected by the disease, which is rapidly replacing Yellow Sigatoka. Black Sigatoka has also been reported recently in the Ivory Coast and in Nigeria in the Port Harcourt area.

A research program to study the pathogenic activity of the fungus was established in Gabon in 1981. Its aim has been to develop improved methods to control the disease and to become better acquainted with the biology and epidemiology of the fungus. Such a program has also been undertaken in Cameroon since November 1985. The research conducted in Africa into *Mycosphaerella fijiensis* has benefited from the work undertaken for many years by IRFA on *Mycosphaerella musicola*.

In our investigation into the biology of the Black Sigatoka pathogen and into the evolution of the disease, we have made use of previous research and are now able to launch a systemic control program for the disease as soon as notification reaches us of new outbreaks.

Although encouraging results have been obtained in our research into chemical control, it seems that the genetic approach is the only control strategy that allows the maintenance of production levels in the long term. Genetic improvement is now given priority in research, with the aim of finding varieties which are resistant or tolerant to Black Sigatoka.

We have studied under conditions of high incidence of Black Sigatoka the behaviour of cultivars belonging to the diploid (AA) and triploid (AAA) *acuminata* groups, and the hybrid triploids AAB and ABB.

We have also completed our studies on phases of incubation and development of the disease along the following parameters: morphological traits of asexual and sexual phases; intensity of sporulation; study of the lateral transportation of ascospores; and distribution of symptoms on the plant.

The evolutionary cycle of *Mycosphaerella fijiensis* comprises, as in the case of all other parasites, two distinct phases: 1) dispersion and establishment, followed by 2) development of the interaction with the host.

Dispersion

Dispersion takes place in two successive stages: release of the inoculum and its dispersal.

Production and Release of Ascospores

The principal factor in the release of ascospores is the rain or, at the minimum, the presence on the leaf of the liquid pellicule, which can also form in the wake of dew or mist. The tissue of the perithecium must be permeated by water. This phenomenon, however, results in one liberation only; others will be achieved if a period of time elapses between two consecutive rains, during which the tissues can dry.

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The tornado (hurricane) season with its short and violent rains, separated by sunny periods, is the most favourable period for the release of the ascospores. The bicellular ascospores can be produced quickly; the precocity of the production depends on a number of factors among which climate is the most important.

If a significant quantity of inoculum is present, and if climatic factors are favourable to the development of the disease, the perithecium will form very quickly; if stages two or three coalesce, necrotic areas will appear on the foliage. The speed with which sexual fructification of the fungus takes place, being proportional to the speed with which lesions evolve, also depends on the cultivar.

Results from Gabon indicate that in humid or equatorial conditions the production of ascospores can continue throughout the year. The Cavendish subgroup, in particular the cultivar Poyo, has always shown significantly higher values for ascospore production compared with other cultivar studies.

Production and Liberation of Conidia

For the majority of the observed cultivars, the study of asexual sporulation in Gabon has shown that the production of conidia by *Mycosphaerella fijiensis* is very low compared to that of *Mycosphaerella musicola* and is strongly affected by the climate.

The first conidiophores become visible with the brown coloration of stage 1, but the production of conidia, even though more abundant during the first stages of the disease, can continue up to the stage preceding the appearance of necrotic areas. It is also subject to significant variations depending on the climate.

There is a correlation between the number of conidia produced and the sensitivity of the cultivar. The most significant values have been obtained with the cultivars Poyo (AAA) and Ebang (plantain AAB) which presented shorter evolutionary periods of the disease, when compared to other cultivars.

In constrast no sporulation could be observed on the cultivar Yangambi, which has shown high resistance to the Black Sigatoka.

Dispersal of the Inoculum

The inoculum (conidia or ascospores) is located at the level of young leaves (production of conidia in the first stages of the disease on the leaves of rows 2 or 3) or at the level of the older leaves.

Dispersal can take place in two directions: 1) conidia are carried downward by water towards the leaves of young sprouts or towards the older leaves of the mother plant (reinfestations); they can also be transported by wind due to the way the spores are attached to the conidiophores. 2) Ascospores are carried towards the young leaves by rising air currents, but are mainly transported laterally by the wind. This mode of dispersal explains why the disease is disseminated over long distances, and why this type of spore acts as the main inoculum.

Host and Parasite Interaction

After the spores have germinated and the germinative tubes have penetrated, if internal conditions are favourable to the development of the fungus, the first symptoms will appear after varying incubation times, and will develop until the host is totally or partially destroyed.

Incubation

The incubation period is defined as the period in the biological cycle of the fungus which follows penetration and ends with the appearance of the first symptom of the disease.

The duration of incubation is a highly variable phenomenon, depending on several factors such as climate, cultivars, and quantity of the inoculum.

For a given temperature, the duration of the incubation period is inversely proportional to the quantity of the inoculum deposited on the leaf. In regions with a regular climate, which is favourable to the disease (regardless of temperature), the quantity of the inoculum is the most important factor.

In Gabon, however, significant variations were recorded as a function of climatic conditions and of the cultivars of the bananas and plantains under study.

The results show that the length of the incubation period is not a sufficiently reliable criterion to determine the susceptibility of a cultivar. There is no correlation between incubation time and susceptibility.

Cultivars such as Yangambi (AAA) and Sweet Plantain (AA) have short incubation times compared to other cultivars, particularly during the period favourable to the disease; the later evolution of the lesions is either blocked at stage 2 (cv. Yangambi, no canker) or is very slow (cv Sweet Plantain).

Symptoms of Black Sigatoka

Stage 1 is the first external symptom of the disease. It appears as a small depigmentation spot whose whitish or yellow colour resembles stage 1 of Yellow Sigatoka disease. These symptoms are not visible in transmitted light and can be observed only on the underside of the leaf.

This stage can be regarded as preceding stage 1 of Meredith and Lawrence (1970), which is manifested by the rusty-brown coloration of the lesion. This symptom becomes distinctly visible due to its transparence.

Stage 2 appears as a stripe, generally brown in colour and visible on the underside of the leaf; later the symptom also appears on the upper part of the limb as a stripe, the yellow colour of which resembles the stripe at stage 1 of Yellow Sigatoka.The colour of this stripe will change progressively to brown and later to black on the upper side of the limb, but will retain the brown colour on the underside.

Stage 3 differs from the previous one by its dimensions. The stripe becomes longer, is enlarged and in certain conditions (weak inoculum and unfavourable climatic conditions) can reach 2 or 3 cm.

Stage 4 appears on the underside as a brown spot and on the upper side as a black spot.

Stage 5 is when the elliptical spot is totally black and has spread to the underside of the limb. It is surrounded by a yellow halo with the centre beginning to flatten out.

Stage 6 is when the centre of the spot dries out, turns clear gray and is surrounded by a well-defined black ring, which is, in turn, surrounded by a bright yellow halo. These spots remain visible after the leaf has dried out because the ring persists.

Evolution of the Lesions

Following the appearance of the first symptom, the disease continues its evolution until the final stage of the lesion's development, when the cankers (which appeared at stage 2 or stage 6 above) coalesce.

The number of leaves still functioning at harvest time depends on the time taken for the lesions to develop. The number of functioning leaves is one of the criteria in determining the sensitivity of a cultivar.

Climatic conditions have a strong influence on the time taken for the lesions to develop; it may be 10 to 36 days with the Ebang (AAB) cultivar; 30–78 days with the Fougamou (ABB) cultivar. In general, apart from the strongly pronounced resistance of the triploid *acuminata* Yangambi (AAA), it is the groups ABB, represented by the cultivars Fougamou and AA, represented by Figue Sucrée, that offer the highest resistance to the Black Sigatoka.

However, significant differences have been observed between cultivars belonging to the same genetic group. This is the case, for instance, with the cultivars Poyo and Yangambi (AAA).

It is, in general, inadvisable to establish a classification of cultivar sensitivity, taking into account only one series of measures carried out during a well-defined climatic period. Research undertaken in Africa has shown that, depending on the effect of the climatic conditions and of the quality of the inoculum, the symptoms continue to develop throughout the year.

Methods of Disease Control

By making use of appropriate notification within the framework of an integrated strategy against Black Sigatoka, the number of chemical treatments employed can be reduced to the minimum while maintaining sanitary conditions still satisfactory for the culture of bananas and plantains. The zone by zone evolution of the disease may be followed by continual analysis of two types of parameters:

1) *Biological parameters* which consist of systematic control on the development of the disease in diverse ecological zones by observations on the foliage of the various stages of the disease.

2) *Climatic parameters*, such as evaporation and temperature, which allow the determination of an effective period of treatment in accordance with the climatic or geographic zone concerned.

In Guadeloupe climatic notification is dominant in the control of Yellow Sigatoka (*Mycosphaerella musicola*). The presence of centres of infestation in certain zones make the maintenance of an observation network obligatory in order to follow the evolution of the pathogen and to report on the effectiveness of the climatic notification system.

The climatic situation is characterised by the evaporation 'Piche' (measured under AMPS); it allows the distinction between conditions more or less favourable to the evolution of the fungus. (Temperature data are no longer taken into account since temperature rarely has a restrictive effect on the fungus.)

The principle of climatic notification is as follows:

The theoretical duration of effectiveness 'd' is estimated on the basis of the last spray treatment beginning with Ep. The weekly evaporation is balanced against the weekly evaporations since the last treatment:

$$dn = 0.5\,EPn \qquad Epn = \frac{En + Ep\,(n - 1)}{2}$$

In Cameroon the control of Black Sigatoka is still based solely on biological notification. Meteorological stations have been installed on 3500 ha of industrial banana plantations, but since the climatic requirements of *Mycosphaerella fijiensis* are not fully understood as yet, reliable climatic notification has not been established.

From fungicidal tests we have found that the principles currently applied for the control of *Mycosphaerella musicola* cannot be systematically transposed to *Mycosphaerella fijiensis*, a pathogenic agent different from the former not only in certain characteristics but also in its pathogenic activity.

Since *Mycosphaerella musicola* strains resistant to Benzimidazoles have appeared in the Antilles, Cameroon, and the Ivory Coast, systemic fungicides belonging to another chemical family had to be employed. The chemical industry has proposed the production of a series of fungicidal molecules whose common function is to act as inhibitors of the synthesis of sterols. Tests so far conducted have allowed us to document and to confirm the excellent action of systemic fungicides of the triazole group on *Mycosphaerella fijiensis*, both in foliar application (oily atomisation) and in distribution for contact with the pseudo trunk.

Other methods at our disposal made possible the treatment of small industrial plantations, difficult to treat from the air. Interesting results have been obtained with fungicides deposited in foliar sheaths.

Notification strategies, making use of systemic fungicides, have significantly reduced the number of treatments in comparison with other systemic processes.

In Guadeloupe, 25 annual treatments have been reduced to 6. In Cameroon, using a system of biological notification in connection with *Mycosphaerella fijiensis* 10–12 treatments are carried out on average each year.

Conclusion

Work on hybridisation for the purpose of creating new varieties has proved difficult with *Musa*, chiefly because of the almost total gametic sterility of all the clones presently cultivated, clones whose fruit development is parthenocarpic.

Methods of improvement at the present time rest essentially on in vitro culture (in vitro fertilisation, mutagenesis, fusion of protoplasts). Nevertheless, taxonomic studies and collections remain very important. Research programs in progress in Cameroon on varietal sensitivity integrate into broader plant improvement programs for banana and plantains.

The different clones tested have enabled us to provide evidence of a continuous gradation in behaviour from extreme sensitivity to resistance. The host-parasite interactions between the host genus *Musa* and the pathogen genus *Mycosphaerella* must be governed by a large number of genes which, as a function of their recombination, confer on *Musa* a gradient of reaction from susceptibility to resistance.

References

Meredith, D., and Lawrence, T.S. 1970. Black leaf streak disease of bananas (*Mycosphaerella fijiensis*): susceptibility of cultivars. Tropical Agriculture (Trinidad), 47, 275–87.