African Journal of Agricultural Research Vol. 6(3), pp. 508-514, 4 February 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.223
ISSN 1991-637X ©2011 Academic Journals

Review

Control of black Sigatoka disease: Challenges and prospects

Ebimieowei Etebu* and Wabiye Young-Harry

Department of Biological Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

Accepted 12 January, 2011

Plantains and bananas are staple food for about 70 million people throughout the humid and sub-humid tropic of Africa. They provide an important source of revenue for small holders who cultivate them. Production, however, has always been threatened by a variety of constraints; the most overriding constraint being black Sigatoka disease caused by a wind-borne fungus, *Mycosphaerella fijiensis* Morelet. As much as 27% of the total cost of production is apportioned to curb the menace the disease. Hence in this write up, the various methods applied so far to control black sigatoka disease in plantains and bananas are reviewed with emphasis on their apparent challenges and prospects. Findings showed that the consumption of plantains and bananas has risen tremendously in recent years, and black Sigatoka disease can be controlled in various ways – culturally, chemically, quarantine, and breeding for disease resistance. A proper management of organic matter using different crop residues as mulch builds up the soil fertility level, and substantially reduced the effect of the disease. The use of forecasting methods could be part of an integrated disease management strategy, as this would reduce the number of fungicide treatment, disease production cost, and partially eliminate pollution challenges. The production and cultivation of disease resistant cultivars in combination with good cultural practices is generally considered to be the most appropriate intervention strategies that would control black sigatoka disease of plantains and bananas.

Key words: Plantain, banana, black Sigatoka disease, *Mycosphaerella fijiensis.*

INTRODUCTION

Plantain and banana are staple food for about 70 million people throughout the humid and sub-humid tropic of Africa. Plantain is eaten fried, baked, roasted, pounded as fufu, prepared as porridge, ground as flour and eaten alone or together with other foods depending on the consumer's desire (Swennen, 1990; Swennen and Vuylsteke, 1991, 1998; Dadzie and Orchard, 1996). Bananas are usually consumed as a snack or used in the preparation of fruit salad, and are rich in vitamins and aid in the normal functioning of the body (Ewusie, 1970). Bananas contain potassium, magnesium, sodium, phosphorous, calcium, iron, copper, iodine manganese, zinc and cobalt (Ewusie, 1970). In addition to being a staple food for rural and urban consumers, plantain and banana provides an important source of revenue for small holders who cultivate them in their compounds or homes gardens as well as in large-scaled field production in the humid and sub-humid tropics (Craenen, 1998; Marín et al., 2003). World production of plantain and banana are estimated at more than 80 million tones annually.

The production of plantains and bananas is however, hampered by a variety of challenges. The most dramatic set-back affecting plantain and banana production for the past 3 decades have been the appearance and spread of black Sigatoka disease (Craenen, 1998; Marín et al., 2003; Meredith, 1970; Rhodes, 1964; Stover, 1978). Black Sigatoka is a leaf spot disease of plantains and banana caused by a wind-borne fungus, *Mycosphaerella fijiensis* Morelet. It attacks species of *Musa acuminata*, *Musa balbsiana* and their inter-specific hybrids. It affects all plantain and most banana cultivars (Swennen, 1990; Gauhl et al., 1993). The fungus *M. fijiensis* attacks leaves, causing their necrosis either partially or entirely, resulting in reduced photosynthetic foliage area (Figure 1).

*Corresponding author. E-mail: eetebu@yahoo.com. Tel: +234-802-982-9015.

Figure 1. Black Sigatoka symptoms and a typical plantain market in the Niger Delta Region of Nigeria. Top left = healthy plantain leaf devoid of Black Sigatoka symptoms. Top right = Early symptoms of Black Sigatoka on a plantain leaf. Bottom left = Advanced symptoms of Black Sigatoka on a plantain leaf. Bottom right = A typical plantain market in Bayelsa State, Nigeria.

This in turn leads to a reduction in yield depending on the extent or severity of the disease. Yield loss of plantain due to black Sigatoka has been reported to be between 20 and 50% during the plant crop cycle (Stover, 1983; Pasberg-Gauhl, 1989; Mobambo et al., 1993). The disease in addition to reducing yield also leads to premature ripening of fruits.

The disease is now pantropic; quickly replaces yellow Sigatoka (*Mycosphaerella musicola* leach) as the dominant leaf spot disease (Craenen, 1998; Meredith, 1970; Mourichon and Fullerton, 1990; Ploetz et al., 1992; Tushemereiwe and Waller, 1993; Wilson and Buddenhagen, 1986). Black Sigatoka is thus considered the most overriding constraints to plantain and banana security of resource poor farmers who cultivate the crop in Africa. As a result, control measures accounting for as much as 27% of the total cost of production (Stover, 1980a, b; Stover and Simmonds, 1987) have been initiated to curb the menace of the disease in plantains and bananas. Additionally, various research programs have been initiated to continually find ways that are more easily adoptable and acceptable by local farmers, cheaper and environmentally safer in the fight to curtail the threat of black Sigatoka disease in plantains and bananas. One of such programs is the International Network for the Improvement of Banana and Plantain (INIBAP), created 1st November, 1984 (INIBAP, 1988). Also in West Africa, the rapid spread of the disease made it first in the priorities of the research program on plantain at the International Institute of Tropical Agriculture (IITA) in Nigeria (Swennen and Vuylsteke 1988).

In this write up, the various methods applied so far to control black Sigatoka disease in plantains and bananas are reviewed with emphasis on their apparent challenges and prospects.

CULTURAL CONTROL

Plants growing in good, fertile conditions would generally show a lower disease severity than plants in poorer soils. Therefore, while proper management of organic matter is already essential for the perennial productivity of plantain, it can also reduce black Sigatoka damage. Compost farmyard manure, crop residue, and alley cropping mulches can thus be exploited to improve the organic matter and nutrients and status of the soil, thereby reducing disease severity and eventually producing higher yields.

Soil fertility has be shown to influence banana and plantain growth and, hence, severity of black Sigatoka. Mobambo and Naku (1993) showed that, there is a correlation between soil fertility and black Sigatoka severity of plantain. Black Sigatoka severity is less on fertile soil than on poor soil. Fertile soils for example with higher soil organic matter content stimulate root ramification, resulting in better water and nutrient uptake and more vigorous plants. Vigorously growing plants carry more functional leaves as they emit new leaves more rapidly, and will thus have relatively lower damage from black Sigatoka disease.

Significant differences in the number of standing leaves, the youngest leaf spotted and the percentage of leaf area with symptoms were found among plantains growing in good against poor soil, for example in homestead gardens against open fields, respectively (Mobambo et al., 1994). Mulching has been an important soil management practice in many parts of the world. Protecting the soil with mulch helps to improve the soil environment which is important for good growth and yields of crops. For example, Ruhigwa (1993) also found that with application of *Pennisetum purpurem* mulch an increase of 21% plantain yield was observed, in the first ration crop compared to the plant crop. The effects of mulching on the growth and yield of plantain have been studied on a number of soils and agroecologies in the tropics. Studies by Obiefuna (1983, 1986) and Swennen and Wilson (1983) showed that, mulching gave higher and more sustained yields in field grown plantains than did the unmulched control. Humus, one of the main products of decomposed organic matter has a physical role in soil structure, chemical role by fixing nutrients and biological role by developing microbial fauna which is necessary in nutrients recycling in the soil. Application of organic manure supplies considerable quantities of nitrogen and phosphorus in the soil. About 80 tons per ha per year of farmyard manure was found to enhance growth, quicker flowering and shorter the flowering to harvest period (Lahav and Turner, 1983).

Apart from mulching, mechanical control, or pruning, based on eliminating necrotic leaf tissue, prevents the disease from spreading to neighboring plants in the plantain. Removing necrotic plantain leaf tissues helps to reduce the amount of inoculum available to infect neighboring plants; hence the percentage of infection, will be greatly reduced. There are different ways of pruning leaves depending on the severity of the disease. Mechanical control methods need to be planned very carefully in order to maintain a sufficient number of leaves to ensure the production of a high quality bunch, as this practice can reduce yield (Tushemereirwe et al., 1998). Also, this method needs to be carried out on a regular basis to keep the plantations clean from infected materials. Some recommendations for this method as recommended by Centre de Recherches Regionales sur Bananiers et Plantains (CRBP) (1991) are:

1. All infected leaves are cut off just before the plant starts flowering, even if the symptoms are not very heavy.
2. All old leaves still hanging at flowering are removed from the plant; else they will be sources of infection on the sucker and young plants.
3. The mother plant is completely removed at harvest.
4. Only the five youngest leaves should be conserved.
5. If the plant has less than five healthy leaves, cut only the infected leaves to conserve the green leaves up to harvest.

After infected leaves have been cut off, there is still a risk of contamination because the spores remain active for several days. Therefore, pruned leaves may have to be removed from the plantation and burned to destroy the fungus completely. Another method is to turn the leaves, face–downwards against the soil since the spores are released from the dry spot on the upper side of the leaf.

CHEMICAL CONTROL

Control of black Sigatoka disease in plantains and bananas could be achieved through the application of chemicals, notably amongst such chemicals are fungicides. Fungicides are defined as “agents of natural or synthetic origin, which act to protect plants against invasion by fungi and/or to eradicate fungal infection” (Hewitt, 1998). Fungicides are generally of two types; protectant and systemic fungicides. Protectants were the first group of fungicides that were discovered and used in crop protection. They are non systemic, and as such do not penetrate plant tissue. Protectant fungicides do not control fungi that are already established within the plant tissues since they do not penetrate the plant tissues themselves.

However, in the late 1960s systemic fungicides were developed. These are more effective than the protectants as they are able to penetrate the plant tissues, and seek to arrest the growth and development of fungal pathogens already established within the plant tissues (Hewitt, 1998; Marín, 2003). Black Sigatoka disease in plantains and bananas has been effectively controlled with the application of fungicides (Fouré, 1983; Marín et al., 2003), particularly when protectant (mancozeb and chlorothalonil) and systemic fungicides (benomyl, benzimidazoles, dethiocarbamates, flusilazoles, imazaliles, methylthiophanates, nuarimols, prochloraz, propiconazoles, triazoles and tridemorph) are used in alternation (Fouré, 1983; Marín et al., 2003). The alternate use of protectants and systemic fungicides is recommended to prevent the fungal pathogen (*M. fijiensis*) from developing resistance to the active ingredient.

Mineral oil has been shown to play several important roles in the chemical control of black Sigatoka. It improves the spreading and sticking properties of fungicides, enhances the penetration of systemic fungicides and has profound effect on the pathogen inside the leaf (Stover, 1990). In addition, oil in itself is fungicidal. The application of oil reduces the disease development in the leaf, since it retards the pathogen development inside the leaf. This control is exerted primarily on the first open leaves, when the pathogen is still in the early stages of development. Oil is effective whether applied as an emulsion in water or alone.

Systemic fungicides (for example, benzimidazole) were however, the first to be used in the control Sigatoka disease in plantains and bananas. They are superior to protectant fungicides, because they penetrate through the upper surface of the youngest unrolled leaves where the pathogen is still in the early stages of infection. Along with oil, the benzimidazole and tridemorph act on the pathogen inside the leaf. Under conditions of heavy rainfall, systemic fungicides provide superior disease control compared to protectants introduced at a later stage (Stover, 1990). Protectant fungicides are more costly and do not adequately control black Sigatoka during periods of high rainfall and abundant ascospore production. The downside of the use of systemic fungicides is that, unlike the protectants, they result to phytotoxicity in plants when applied during dry seasons. The superiority of systemic fungicides over the protectants would therefore be best limited to the rainy seasons.

Breeding for resistance

Resistance to black Sigatoka in banana and plantains is genetically controlled. Genetic analysis of the effect of black Sigatoka resistance carried out in diploid and tetraploid progenies were obtained from triploid (Plantain) X diploid crosses (Ferreira et al., 2004; Vuylsteke et al., 1993c). Black Sigatoka resistance is mainly the result of the interaction between the recessive allele at a major locus (bs) and those of at least two independent minor genes with additive effects (bsr) (Ortiz and Vuylsteke, 1994). These genes have a strong dosage effect at the tetraploid level, which results in higher level of resistance in tetraploid than in diploid hybrids. Resistant genes are present in the genome of the susceptible plantains, but their expression is masked by the dominant effect of the major gene for susceptibility (Ortiz and Vuylsteke, 1994). Using the gene-for-gene hypothesis (which states that the characteristics of an organisms are controlled by genes occurring in pairs, of a pair of such genes only one can be carried in a single gamete) (Flor, 1971), a host plant resistance system based in recessive alleles is difficult to overcome by the pathogen, as this requires a mutation to the dominant allele of the virulence locus (Ortiz and Vuylsteke, 1994); since such mutations are rare (Simmonds, 1979), resistance based on recessive alleles may suffice.

Breeding for resistance offers the most effective means of control since fungicides are expensive and hazardous to health. To this effect, IITA started a plantain breeding program in 1988 at Onne, targeting the incorporation of durable host plant resistance to black Sigatoka in plantain. Several black Sigatoka-resistance tetraploid hybrids (TMPx, FHIA) have been produced by crossing triploid plantain cultivars with a wild diploid banana (Hernández et al., 2007; Swennen, 1990; Swennen and Vuylsteke, 1993; Ortiz and Vuylsteke, 1998a, b; Ortiz et al., 1998). The use of black Sigatoka-resistant genotypes is an important component of an integrated approach. Durable resistance to black Sigatoka is the result of an overall gene action or the bs I locus. As a consequence, resistant genotype show more healthy leaves, that is to say, more photosynthetic leaf area, than susceptible genotypes (Craenen and Ortiz, 1998). At IITA, improved hybrid of plantain and banana selected for their black Sigatoka resistance, high yield and large pathenocarpic fruit have been developed and registered in the Public domain (Vuylsteke et al., 1993b, c, 1995). Hybrids selected in preliminary yield trails were evaluated in multilocational trials by collaborating nationals programs in Burundi, Cameroon, Côte d'Ivoire, Ghana, Kenya, Malawi, Nigeria, Uganda, and Zanzibar (Mobambo et al., 1993; Msogoya et al., 2006; Msogoya and Grout, 2008; Vuylsteke et al., 1993b, c). The result provided valuable information of black Sigatoka resistance in the new tetraploid hybrids.

QUARANTINE

This involves the use of legislative laws governing the important and exportation of plantains and banana. This method is reported to be actively pursued in Australia (Jones, 1991).

CHALLENGES AND PROSPECTS

Simmonds (1979) suggested that disease damage could only be adequately assessed when comparing the same cultivar under pesticides and non-pesticides conditions. Mobambo et al. (1993) demonstrated that a fungicide treatment on the susceptible plantain cultivar Obino l'Ewai (OL) resulted in 27.5% less leaf area affected by black Sigatoka at harvest. Other diseases were not treated OL was due to fungicide use and the resulting different levels of black Sigatoka damage. The 33% yield loss from black Sigatoka reported from this experiment can be considered as the minimum, because the fungicide treatment did not provide complete control. With an optimized fungicide program, yield difference should be even greater. Chemical control strategies exist and are used intensively in the large export Plantation in Central and South America. Yet, the high cost of labour, materials and equipment required for chemical control cannot be overlooked. Small and medium size plantations either disappear on farmers from co-operative to finance chemical control strategies. Chemical control is not feasible for resource-limited farmers.

Moreover, the applications of fungicides in small villages are likely to be hazardous to public health and are environmentally inappropriate. Also, the appearance of fungicide resistant strains of the pathogen overcomes chemical control strategies. After using an increased number of spray cycles with systemic fungicides during some years, fungicide resistant strains of *M. fijiensis* appeared, putting more pressure on the search for new strategies (Stover, 1990). Therefore, for producers who cannot afford fungicides, such as small-holders in Africa, the utilization of resistant Musa cultivars is a more appropriate solution to control black Sigatoka (Vuylsteke et al., 1993a).

Although the benefits of mulching plantain and banana as well as other food crops have been amply demonstrated, the logistic in production, transport and application limits the use (Akobundu, 1987; Nweke et al., 1988; Ruhigwa, 1993). Also, the acceptance of new technologies (alley cropping) by peasant farmers is difficult. Plantain, like many other crops benefits from mulch and fertilizer applications (Juo and Lal, 1977; Oyeniji and Agbede, 1980). The shorter leaf emergence time observed and the concomitant increase in growth rate suggest that mulching and fertilizer applications can be used to improve plantain, especially in the landrace. Wilson et al. (1985) obtained a better result when fertilizer and mulch were applied together than singly. In breeding for black Sigatoka resistance, some hybrid known to black Sigatoka resistant are highly susceptibility to a more lethal pathogen, Banana Streak Virus (BSV). This is a huge challenge. Now that it is apparent that some of the hybrids are severely affected by BSV, an urgent study for its control and its association with black Sigatoka as Musa pathogens are necessary.

Another challenge linked to breeding for black Sigatoka resistance is the fact that, the response of the resultant Musa hybrids to the disease is often investigated by planting them (hybrids) among susceptible landraces such as Obino 'Lewai and Agbagba; the latter serving as source of inoculum. This approach is greatly flawed because strains of the pathogen *M. fijiensis* are very much diverse, genetically and in virulence (Carlier et al., 1994, 1996; Fullerton and Olsen, 1991; Müller et al., 1995, 1997). An unbiased test aimed at comparing the response of different Musa cultivars to black Sigatoka would involve inoculating all cultivars being tested with the same amount of inoculum (conidia) from the same strain or isolate of the fungus (Mobambo and Waku, 1993). This requires producing enough inoculum (conidia) *in vitro* which until recently was difficult to achieve owing to the slow-growing nature of the fungus (Mobambo et al., 1993; Pasberg-Gauhl, 1994). Although, Etebu et al. (2005) has found various factors that would stimulate *in vitro* sporulation of *M. fijiensis* isolates their findings are yet to be translated into practical use. Adaptability of hybrids to different climates is also desirable, since climatic conditions influence the disease development. Black Sigatoka disease is spread by wind-dispersed spores and therefore has defied quarantine control regulations. It has become the over-riding constraint to plantain production all over the world (Stover, 1983; Simmonds, 1983; Fouré, 1985). Mechanical method of control is less efficient in controlling the spreading pathogen, but is less time-consuming. The development of the disease can thus be somewhat reduced by preventing the release of spores without high costs or damage to the environment. However, this method is labour-intensive, which makes it costly where labour is expensive.

CONCLUSION

Bananas and plantains are important food crops in Nigeria. Its consumption has risen tremendously in recent years because of rapidly increasing urbanization and the great demand for convenient foods by the non-forming urban population. Any efforts made towards protecting it from the cold hands of pests and disease is worthwhile. This review work has shown how black Sigatoka disease of plantains and bananas can be controlled in four different control measures. The adoption of the farmers' field practice and alley with medium and high fertilizer application increased growth substantially. A proper management of organic matter using different crop residue as mulch could build up the soil fertility level, and would substantially reduce the effect of black Sigatoka. The use of forecasting method can be part of integrated management strategy for leaf spot disease of bananas and plantains. It can reduce the number of fungicide treatment, disease production cost, and partially eliminate pollution problem.

Similarly, plantains and bananas like any other crop require adequate fertilization, for proper growth and development. As earlier discussed the yield from fertilized plants can be up to ten times higher than that from unfertilized plants. The production and cultivation of resistant cultivars in combination with good crop management practices is generally considered to be the most appropriate intervention to control black Sigatoka disease. Improved black Sigatoka resistant genotypes could be easily adopted by African farmers as new cultivars, if they fit their production and consumption system.

REFERENCES

Akobundu IO (1987). Weed Science in the tropics. Principle and Practices. John Wiley and Sons: pp 85 – 86.

Craenen K (1998). Black Sigatoka disease on Bananas and Plantains. A reference manual International Institute of Tropical Agriculture, Ibadan, Nigeria. pp 2 – 8.

Craenen K Ortiz R (1998). Influence of black Sigatoka disease on the growth and yield of diploid and tetraploid hybrid plantains. Crop Protection 7: 13 – 18.

CRBP (1997). Agro-phytopathologic observatory : Black Sigatoka in Plantain. The Technical Report on the month, Plantain News 32-7-9.

Dabek AJ, Walter JM (1990). Black leaf streak and Viral leaf streak: New banana disease in East Africa. Trop. Pest Manage. 36: 157 – 158.

Dadzie BK, Orchard JE (1996). Post Harvest Criteria and method for routine screening of Banana and Plantain hybrids. International

Network for the improvement of Banana and Plantain (INIBAP) Montpellier, France. pp 1 – 40.
Etebu E Okorie E (2009). Inhibitory effect of plantain fruit peel extract on *in vitro* germ-tube formation of *Mycosphaerella fijiensis* (causal agent of black Sigatoka disease on plantains and bananas). Niger. J. Plant Protection. 23: 53-62.
Etebu E Pasberg-Gauhl C Gauhl F (2005). Effect of Light and Sealing Patterns on Sporulation and Growth of Mycosphaerella fijiensis. InfoMusa 14: 24-25.
Ewusie JY (1970). School certificate biology for Tropical Schools. 2nd Edition George G. Harrap and Co. Ltd., London. pp, 167 – 180
Ferreira CF, Silva SO, Sobrinho NPD, Cristina S, Damascena S, Alves FS, Paz OP (2004). Molecular Characterization of Banana (AA) Diploids with Contrasting Levels of Black and Yellow Sigatoka Resistance. Amer. J. Appl. Sci., 1: 276-278
Flor HH (1971). Current Status of the gene-for-gene concept.Ann. Rev. Phytopathol 9: 275–296.
Fouré E (1983). Les Cercosporioses du bananier et leurs traitments. Selection de molécules fungicides nouvelles. Activités Comparées de différentes molécules fungicides sur Mycosphaerella fijiensis Morelet, agent de la ‘‘maladie des raies noires’’ des bananiers et plantains de Gabon. Fruit 38: 21–34.
Fouré E (1985). Les Cercosporioses du bananier et leurs traitments. Comportement des variétés. Etude de la sensibilité Variétale des bananiers et Plantains á Mycosphaerella fijiensis Morelet au Gabon (Maladies des raise noires) (Suite III). Fruit 40: 393–399.
Fullerton RA, Oslen TL (1991). Pthogenic variability in Mycosphaerella fijiensis Morelet. In Valmayor, RV., Umai, B. E. and Bejosano, C. P. (eds.). Banana diseases in Asia and the pacific. Proceedings of a tehnical meeting on diseases affecting banana and plantain in Asia and the pacific, Brisbane, Australia, 15-18 April, 1991. Montpellier, France: INIBAP, pp. 105-114.
Gauhl F (1994). Epidemiology and ecology of black Sigatoka disease (Mycosphaerella fijiensis Morelet) on plantain and banana in Costa Rica, Central America` INIBAP. Montpellier, France. p. 120.
Gauhl F, Pasberg–Gauhl C, Vuylsteke D, Ortiz R (1993). Multilocational evaluation of black Sigatoka resistance in banana and plantain. IITA research guide No.47. IITA, Ibadan Nigeria pp. 59.
Gauhl F, Pasberg–Gauhl C (1994). Epidemiology and ecology of Black Sigatoka disease in Nigeria. Phytopathology, pp. 84:100.
Hewitt HG (1998). Fungicides in crop protection. CAB International, Wallingford, UK. p. 221.
INIBAP (1988). International Network for the improvement of Bananas and Plantains. Montpellier, France, p. 27.
Johnson A, Jerger MJ (1993). Use of PCR for detection of Mycosphaerella fijiensis and M. musicola, the casual agents of Sigatoka leaf spots in banana and plantain. Mycological Res., 97: 670 – 674.
Jones DR (1991). Banana Quarantine in Australia. In: banana disease in Asia and the Pacific Proc. Of a Reg. Tech. Meeting on diseases affecting Banana and Plantain in Asia and the Pacific, Brisbane, Australia, 15 – 18 April 1991 (Ed) Valmayor, R.V. pp. 133–143.
Jones DR Mourichon X (1993). Black leaf streak/black Sigatoka disease. Musa disease fact sheet No.2 INIBAP, Montpellier, France.
Juo A, Lal R (1977). The effect of fallow and continous cultivation on the chemical and physical properties of an Alfisol in Western Nigeria. Plant Soil, 47: 567 – 584.
Lahav E, Turner DM (1983). Fertilizing for high yield. Banana nutrition, IPI-BILL. No.7, pp. 62.
Marín DH, Romero RA, Guzmán M, Sutton TB (2003). Black Sigatoka: An increasing threat to banana cultivation, Plant Diseases 87: 208 – 222.
Meredith DS (1970). Banana leaf spot disease (Sigatoka) caused by Mycosphaerella musicola Leach. Phytopathological papers No.11. Kew, England: Commonwealth mycological institute.
Meredith DS, Firman ID (1970). Banana leaf spot in Fiji. Tropical Agriculture, 47: 127 – 130.
Meredith DS, Lawrence JS (1969). Black leaf streak disease of bananas (Mycosphaerella fijiensis) symptoms of disease in Hawai, and notes on the conidiae state of casual fungus. Trans. Br. Mycol. Soc. 52: 457 – 476.
Mobambo KN, Gauhl F, Vuylsteke D, Ortiz R, Pasberg-Gauhl C, Swennen R (1993). Yield loss on plantain from Black Sigatoka leaf spot and field performance of resistant hybrids. Field crops Res., 35: 35 – 42.
Mobambo KN, Naku M (1993). Situation de la cercosporiose noire desbananiers et plantains (Musa spp) sous différents systémes de culture á Yangambi, Itaut – Zarie. Tropicultura 11 :7-10.
Mobambo KN, Zuofa K, Gauhl F, Adeniji MO, Pasberg-Gauhl C (1994). Effect of soil fertility on host response to black leaf streak of plantain (Musa spp, AAB group) under traditional farming systems in Southern Nigeria. Inter. J. Pest Manage., 4091: 75 – 80.
Morelet M (1969). Micromycetes du var et d’alleuts (2e note) Annales de la Société des Sciences naturalles et archéologiques de Toulon et du var 21: 104 – 108.
Mourichon X, Fullerton RA (1990). Geographical distribution of the two species Mycosphaerella musicola Leach (Cercospora musae) and Mycosphaerella fijiensis Morelet (C. fijiensis), respectively, agents of Sigatoka disease and black leaf streak disease in bananas and plantains. Fruits 43(3): 213–218
Msogoya TJ, Maerere AP, Kusolwa PM, Nsemwa LT (2006). Field Performance of Improved Banana Cv. Fhia 17 and Fhia 23 in the Eastern Zone of Tanzania. J. Agron., 5: 533-535
Msogoya T, Grout B (2008). Altered Response to Biotic and Abiotic Stress in Tissue Culture-Induced Off-Type Plants of East African Highland Banana (Musa AAA East Africa), J. Appl. Sci., 8: 2703-2710
Mulder JL, Stover RH (1976). Mycosphaerella species causing banana leaf spot. Transactions of the British Mycological Society 67: 77 – 82
Müller R, Pasberg-Gauhl C, Gauhl F, Kaemmer D, Kahl G (1995). Tracing microsatellite polymorphism within the Nigerian population of Mycosphaerella fijiensis, INFOMUSA, 4: 9-11
Müller R, PasbergGauhl C, Gauhl F, Ramser J Kahl G (1997). Oligonucleotide fingerprinting detects genetic variability at different levels in Nigerian Mycosphaerella fijiensis, J. Phytopathol., 145: 25-30.
Njoku JG (1990). Socio-economic aspects of plantain production in the humid tropic. Plantain Research and Technology Transfer, IITA, Ibadan, pp. 13.
Nweke FI, Njoku JE, Wilson GF (1988). Productivity and Limitations of Plantain (Musa spp. CV. AAB). Production in compound gardens in Southeastern Nigeria Fruits 43: 161 – 166.
Obiefuna JC (1983). The effect of Sawdust mulch and increasing cereals of Nitrogen on the growth and yield of plantain (Musa AAB sub group). Pro. Annu. Meet. West Africa Regional Co-operative for Research on plantains, IITA, Ibadan, Nigeria, 5 – 9 December, 1993, Ibadan, Nigeria.
Obiefuna JC (1986). Crop wastes and plantain (Musa AAB) production in the tropical rainforest of Nigeria. 8th Annu. Conf. Hoticult. Soc. Nigeria. NIRHORT, Ibadan, Nigeria. 9 – 15 November, 1986, IITA, Ibadan, Nigeria
Ortiz R, Vuylsteke D (1994). Inheritance of black Sigatoka disease resistance in Plantain – banana (Musa spp) hybrids. Theor. Appl. Gen., 89: 146 – 152.
Ortiz R, Vuylsteke D (1998a). PITA – 14: a black Sigatoka-resistant tetraploid plantain hybrid with virus tolerance. Hortiscience 33: 360 - 361.
Ortiz R Vuylsteke D (1998b). BITA – 3’: a starchy banana with partial resistance to black Sigatoka and tolerance to streak virus. Horticience 33: 358 – 359
Ortiz R, Vuylsteke D, Crouch H, Crouch J (1998). TM3x: triploiud black Sigatoka-resistant Musa hybrid germplasm. Hortiscience 33: 362 – 365.
Oyeniyi S, Agbede O (1980). Soil organic matter and yield of forest tree crops. Plant soil, 57: 61 – 67.
Pasberg–Gauhl C (1989). Untyersuchanger Zur symptomentwicklung and bekampfung der Schwarzen Sigatoka – Kranheit Mycosphaerella fijiensis Morelet on Bananen (Musa spp). In vitro und un freiland. Gottinger Beitrage zur landund Frostwirt Schaft in den Tropen Und Subtropen, Heft 40.
Ploetz RC, Channer AG, Chizala CT, Banda D, Lna PW, Braunworth Jr WS (1992). A current appraisal of banana and plantain disease in Malawi. Trop. Pest Manage. 38: 36 – 42
Rhodes PL (1964). A new banana disease in Fijji, Commonwealth Phytopathol News 10: 38 – 41

Runhigwa R (1993). Alley cropping of plantain with Dactyladenia barberi, Alchomea Cordifolia, Senna Siamea and Gmelina arborea hedgerocos on an ultisol in Rivers State, Nigeria Ph. D. Thesis, Rivers State University of Science and Technology, Nigeria, p. 178

Sebasigari K (1987). Morphological taxonomy of Musa in Eastern Africa. Pages 172–176 in Banana and plantain breeding strategies: Proceedings of an international workshop held at Cains, Australia, 13 – 17 Oct. 1986, edited by G. J. Persley and E. A. De Langhe ACIAR proceedings No.21, Canberra, Australia.

Sebassigari K, Stover RH (1988). Banana disease and Pest and Pest in East Africa: Report of a Survey made in November 1987 INIBAP/88/02. INIBAP, Montpellier, France. p.15.

Simmonds NW (1948). Genetical and Cytological studies of Musa x. Stomatal size and plant vigour in relation to polypoidy. J. Genet., 49: 57 – 68.

Simmonds N. W. (1966).Bananas, 2nd Edition. Longman, London, UK, and New York, U. S. A.

Simmonds NW (1979). Principles of crop improvement. Longman. London, UK and New York, U.S.A.

Simmonds NW (1983), Classification et amélioration génétique de la banane Acte du colloque regional tenu á Bujumbura, Burundi du 14 au decémbre 1983, pp. 77–85.

Simmonds NW (1987). Classification and breeding of banana and plantain strategies (ED. By G. J. Perseley and E. A. De Langhe), pp 78 – 83. INIBAP and ACIAR Procedings No.21 Cairns, Australia.

Skutch AF (1927). Anatomy of the leaf of banana Musa sapientum L, var. hort Gros Michel Botanical Gazette 34: 337–391

Stover RH (1972). Banana, Plantain and Abaca diseases. Commonwealth Mycological Institute, England, pp. 316.

Stover RH (1978). Distribution and probable origin of Mycosphaerella fijiensis in Southern Asia. Tropical Agriculture (Trinidad) 55: 65 - 68

Stover RH (1980a). Sigatoka leaf spot of bananas and plantains. Pages 1–18 in proceedings of the Sigatoka workshop, 18-19 Feb. 1980. La lima, Honduras, edited by D. T. Krigvold and T. L. Woods United Fruit Company, La lima, Honduras

Stover RH (1980b). Sigatoka leaf spots of bananas and plantains. Plant disease 64: 750 –756.

Stover RH (1983). Effect du cercospora noir sur les plantains en Amerique centrale. Fruits 38: 326–29.

Stover RH (1990). Sigatoka leaf spots: Thirty years of changing control strategies: 1959–989. In: Sigatoka leaf spot disease of bananas (Ed. By R. A. Fullerton and R. H. Stover), pp 64 – 74. inibap PROCEEDINGS, San Jose, Costa Rica.

Stover RH, Simmonds NW (1987). Bananas. 3rd Edition. Longman Scientific and Technical, Essex, England, UK. pp. 468

Swennen R (1990). Plantain cultivation under West African conditions: A reference munual. International Institute of Tropical Agriculture, Ibadan, Nigeria. pp. 24.

Swennen R, Vuylsteke D (1991). Bananas in Africa: diversity, uses and prospects for improvement. Pages 151 – 160 in. Crop Genetic Resources of Africa, Vol. 2. Edited by N. Q. Ng, P. Perrino, F. Attere, and H. Zedan, IITA/CNR/IBPGR/UNEP. Copublication, Trinity Press, UK.

Swennen R, Vuylsteke D (1993). Breeding black Sigatoka resistant plantains with a wild banana. Trop. Agric. 70: 74 – 78

Swennen R, Vuylsteke D (1998). Plantains in West and Central Africa: Importance, production and prospects for improvement. Page 15 in 4th West and Central African Root Crop workshop, Lome, Togo, 12 – 16 December, 1988, IITA, Nigeria.

Swennen R, Vuylsteke D, Ortiz R (1995). Phenotypic diversity and patterns of variation in West and Central Africa Plantains. Econ, Bot., 49: 320 – 327.

Swennen R, Wilson GF (1983). Response of plantain to mulch and fertilizer. International Institute of Tropical Agriculture Annu. Rep., IITA, Ibadan, Nigeria, pp. 187.

Tezenas du Motcel H (1987). Plantains and bananas, The Agriculturist. CTA, Macmillan. p. 106.

Tushemereiwe WK, Waller JM (1993). Black leaf streak (Mycosphaerella fijiensis) in

Uganda. Plant Pathol., 42: 471–472

Tushemereiwe WK, Holderness M, Gold CS, Karamura EB, Deadman M (1998). Effect of the leaf spot complex and leaf pruning on highland bananas. Proceedings of the first conference on Banana and Plantain for Africa. Kampala 1996. Acta Horticulture, in Press.

Vasquez N, Tapio AC, Galindo JJ (1990). Ultrastructural studies of the infection process of Mycosphaerella fijiensis on Musa cultivars. Pages 191 – 200 in Sigatoka leaf spot disease if bananas: proceedings of an International workshop, San Jose, Costa Rica, 28 March – 1 April 1989, edited by R. A. Fullerton and R. H. Stover. International Network for the improvement of banana and plantain, Montepellier, France.

Vuylsteke D, Ortiz R, Ferris S, Swennen R (1995). 'PITA-9': a black Sigatoka-resistant hybrid from the 'False Horn' plantain gene pool. Hortiscience 30: 395 – 397.

Vuylsteke D, Swennen R (1988). Preliminary report on the vigour and black Sigatoka reaction to some East Africa bananas cultivated under humid lowland conditions in Nigeria. Musarama, 1: 2- 3.

Vuylsteke D, Ortiz R, Pasberg-Gauhl C, Gauhl F, Gold C, Ferris S, Speijer P (1993a). Plantain and banana research at the International Institute of Tropical Agriculture. Hortiscience 28: 873–874; 970 – 971

Vuylsteke D, Swennen R, Ortiz R (1993b). Registration of 14 improved tropical Musa plantain hybrid with black Sigatoka resistance. Hortiscience 28: 957–959.

Vuylsteke D, Swnennen R, Ortiz R (1993c). Development and performance of black Sigatoka-resistance tetraploid hybrids of plantain (Musa spp, AAB group) Euphytica 65: 33–42.

Wilson GF, Buddenhagen I (1986). The black Sigatoka threat to plantain and banana in West Africa. IITA Research Briefs 7(3): 899.

Wilson GF, Swennen R, De Langhe DE (1985). Effects of Mulch and fertilizer on yield and longevity of a medium and giant plantain and a banmana cultivar. Proc. 3rd Meet., Int. Assoc. Res. Plantain and Banana. Abidjan, Cote D'Ivoire, 27(31): 109–111.