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Factors Influencing the Development of Black Streak Disease and the Resulting Yield Loss in Plantain in the Humid Forests of West and Central Africa

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ABSTRACT

Plantain, an important staple food crop in the humid tropics, is threatened by black leaf streak (*Mycosphaerella fijiensis* Morelet), an airborne fungal leaf spot disease. Due to limitations associated with the use of chemicals in Africa, cultural practices are used to minimize the disease effect on crop yields. Research on breeding for resistance has been undertaken at the International Institute of Tropical Agriculture (IITA) and plantain hybrids have been produced. Studies on black leaf streak severity were conducted in Central Africa on plantain and in West Africa on both plantain and tetraploid hybrids of plantain to identify the factors involved in the disease development. These are the environmental and biological factors to which growth and yield performances of the crop are also related. Over cropping cycles, plantain is much affected by the complex of disease, pests and soil fertility decline which together can reduce yield by more than 90%, when calculated from the difference in yield between the plant crop (first cycle) of the fungicide-treated and the ratoon crop (second cycle) of the non-treated plantain. Thus, proper management of soil organic matter for the sustainable productivity of plantain is considered as the most feasible and realistic approach reducing the black leaf streak severity with low inputs and good fruit quality in Africa.

Keywords: Africa, bananas, disease severity, *Mycosphaerella fijiensis*, soil fertility, yield loss
Abbreviations: BLS, black leaf streak; **DRC**, Democratic Republic of Congo; **FT**, fungicide-treated; **INIBAP**, International Network for the Improvement of Banana and Plantain; **IITA**, International Institute of Tropical Agriculture; **LSD**, least significant difference; **LAWS**, leaf area with symptoms; **LTL**, life time of leaf; **NSL**, number of standing leaves; **NT**, non-treated; **OL**, Obino l'Ewai; **PC**, plant crop; **RC**, ratoon crop; **TMPx**, IITA Tetraploid Hybrids; **YLS**, youngest leaf spotted

CONTENTS

INTRODUCTION

Plantain (*Musa spp*. AAB group) is a crop of tropical humid forest zones and is cultivated in Africa from the lowlands of Guinea to the central basin of Congo. It is an integral component of most farming systems in West and Central Africa, where about 50% of the world's plantain is produced (FAO 1998; Akyeampong 1999). Within this region, Democratic Republic of Congo (DRC) and Nigeria are the countries which produce most plantain (Wilson 1987; FAO 1998) and where it is the cheapest carbohydrate food (Flinn and Hoyoux 1976). Traditionally, plantain is grown around the homestead in many rural areas where it is produced. It is mainly grown by small-scale farmers whose families consume the crop and sell any surplus in the local market. However, considering its economic importance, commercial farms of plantains are sprouting up in West and Central African countries. Therefore, it contributes significantly to the incomes of rural households in major producing areas.

In spite of its importance to local people, plantain was ignored for a long time by agricultural researchers in the region, since it had no major disease problems until the 1970s and was therefore regarded as a disease-free crop in Africa (Wilson 1987). This picture changed in 1978 when black leaf streak (BLS), also called black Sigatoka, an airborne fungal leaf spot disease, caused by *Mycosphaerella fijiensis* Morelet, was reported in Gabon (Frossard 1980). The disease spread rapidly into Cameroon in 1980 (Fouré 1985, 1987) and Congo in 1985 (Mourichon 1986). In 1986, BLS was detected in southeastern Nigeria (Wilson and Buddenhagen 1986). The disease was also identified in East and Central African countries, Burundi in 1987, and in Rwanda and DRC in 1988 (Sebasigari and Stover 1988; Mobambo and Naku 1993; Mobambo *et al*. 1993a).

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Invited Mini-Review

BLS spreads by wind-dispersed spores and is thus beyond the control of plant quarantine measures. The production and movement of fungal inoculum (conidia and ascospores) depend on the ecological conditions (Stover 1972; Fouré 1987; Gauhl 1989; Gauhl and Pasberg-Gauhl 1994; Jones 1999). Currently, BLS is the most destructive leaf disease of plantain as it is spreading inexorably to all major plantain growing regions. BLS attacks leaves, causing their necrosis, resulting in reduced photosynthetic foliage area and eventually reducing yields. The disease not only reduces yield, but also leads to premature ripening of fruits. Plantain yield losses of 33% in the plant crop and 76% in the ratoon crop cycles have been estimated at the International Institute of Tropical Agriculture (IITA), Onne, southeastern Nigeria (Mobambo *et al.* 1993b, 1996a). Hence, BLS is considered as a major constraint to plantain production and is therefore endangering the food security of resource poor farmers who grow the crop.

BLS can be controlled by either contact or systemic fungicides (Fouré 1983; Jones 1999). In Africa however, chemical control strategies are not affordable for the small-scale farmers, since fungicides are expensive and difficult to procure. In addition, fungicide applications are environmentally inappropriate and may be hazardous to the health of people in the villages where the bulk of plantain is grown. In the homestead gardens, plantain yield was estimated to be nearly four times that obtained in the far fields (Nweke *et al.* 1988), because the crop benefits from household refuse and other kitchen waste. Soil organic matter plays a major role in the host-plant performance of homesteads. In the homesteads plantain can be productive for about 25 years, while in the fields it is grown for about 3 years only (Mobambo *et al.* 1994a).

This report summarizes results of studies on the evaluation of BLS development on plantain under different farming systems and the assessment of yield loss over cropping cycles in the northeastern Congo and southeastern Nigeria.

BLACK LEAF STREAK DEVELOPMENT

Central Africa

1. On-farm survey of BLS disease

In DRC, the northeastern region, Yangambi area, which is the humid forest zone straddling the equator, is the main plantain producing area. An on-farm survey of BLS disease was carried out in this region in 1988/89 in two different crop management systems namely field plantations and homestead gardens. To evaluate the host response to BLS, the following parameters were used: percentage of leaf area with symptoms (Stover and Dickson 1970; Stover 1971), youngest leaf spotted (Meredith and Lawrence 1970; Fouré 1987) and the number of standing leaves both at flowering and harvest (Meredith and Lawrence 1970).

The survey indicated that all plantain cultivars evaluated either in fields or in homesteads were susceptible to BLS disease (Mobambo and Naku 1993). However, significant differences were found between field plantations and homestead gardens for all the parameters evaluated (**Table 1**). BLS severity was less on plantain growing in homesteads than in fields. Soil organic matter was considered as playing a major role in the host-plant performance of homesteads compared to fields, as the organic household waste added to plantain is the most obvious difference between the two farming systems. Since household refuse and mulch regularly applied in homesteads cover the soil, they reduce soil temperature and therefore stimulate root ramification in plantain (Swennen *et al.* 1988). The increased root ramification is correlated with a better sucker development which reflects a higher nutrient uptake by plantain.

Table 1 Influence of farming system on number of standing leaves at flowering (F) and at harvest (H), youngest leaf spotted at flowering and percentage of leaf area with black leaf streak symptoms at flowering of plantain, Yangambi, northeastern Congo.

Farming system	Number of standing leaves		Youngest leaf spotted	% Leaf area with symptoms
	F	H		
Field	5.7	2.1	4.9	22.2
Homestead	7.5	3.8	6.9	17.1
LSD* (0.05)	1.2	0.7	0.9	2.1

*LSD : Least significant difference

2. On-station evaluation of BLS disease in plant crop cycle

In 1998, an experiment was carried out, in Kinshasa zone, western Congo, in a randomized complete block design with five plot-treatments based on cultural practices: crop residues mulches (wood sawdust, rice husk), cover crop (*Vigna unguiculata*) and fertilizers (NPK). Non-treated plants were used as control. For each treatment soil samples were analysed, BLS evaluated every week and yield components recorded.

Results on soil analysis (**Table 2**) showed that the amounts of soil nutrients were higher in the mulched plots than in the other plots. Crop residues mulches constitute better sources of nutrients and act therefore as fertilizer (Mobambo 2002). According to Lal and Kang (1982), organic matter is a key component of soil fertility, as a reservoir of nutrients, as a main source of cation exchange capacity and as major promoter of aggregate structural stability.

Regarding BLS evaluation, symptom development in the mulched plantain was slower than in the non-mulched plantain (**Table 3**). In the plantain mulched with crop residues, BLS needed almost one month more to develop the last symptom stage compared to the control. For the fertilized and cover-cropped plantain, symptom evolution time values were, respectively, 40 and 36 days, i.e. 2-3 weeks less than for the mulched plantain.

For all parameters evaluated, plantain mulched with crop residues performed better than those that were non-

Table 3 Host response to black leaf streak of plantain under different management practices at Kinshasa, western Congo.

Cultural practice	Symptom evolution time (days)	Youngest leaf spotted	% Leaf area with symptoms	Life time of leaf (days)
Control	23.2 a	5.5 a	19.6 d	62.5 a
Wood sawdust	50.0 c	9.3 c	4.2 a	125.7 d
Rice husk	56.8 c	10.9 d	3.8 a	130.3 d
Vigna unguiculata	35.5 b	7.5 b	10.3 c	80.3 b
N-P-K	40.0 b	8.1 b	6.9 b	103.3 c

Within columns, means followed by the same letter are not significantly different at $P < 0.05$, according to Duncan's multiple range test.

Table 2 Selected soil chemical properties under different plantain management practices at Kinshasa, western Congo.

Cultural practice	pH (H_2O)	Organic C (%)	Total N (%)	Exchangeable cations (meq/100 g)		
				Ca	Mg	K
Control	4.2 a	1.15 a	0.11 a	1.22 a	0.21 a	0.15 a
Wood sawdust	6.2 c	3.51 c	0.25 b	6.51 c	1.87 c	0.87 c
Rice husk	6.8 d	3.79 d	0.28 b	7.52 d	2.10 c	0.98 d
Vigna unguiculata	5.2 b	2.15 b	0.22 b	4.07 b	0.78 b	0.46 b
N-P-K	5.6 b	2.23 b	0.26 b	5.63 c	1.06 b	0.96 c

Within columns, means followed by the same letter are not significantly different at $P < 0.05$, according to Duncan's multiple range test.

Table 4 Yield parameters of plantain under different management practices at Kinshasa, western Congo.

Cultural practice	N° of hands per bunch	N° of fruits	Bunch weight (kg)	Yield (t/ha)
Control	6.0 a	75 a	9.5 a	15.8 a
Wood sawdust	6.5 b	88 c	15.0 c	25.0 c
Rice husk	6.5 b	90 c	17.5 d	29.2 d
Vigna unguiculata	6.2 a	82 b	11.0 a	18.3 a
N-P-K	6.2 a	87 bc	13.0 b	21.7 b

Within columns, means followed by the same letter are not significantly different at $P < 0.05$, according to Duncan's multiple range test.

Table 6 Host response to black leaf streak of the False Horn plantain cv. 'Agbagba' under fields and homesteads in different geomorphological zones of Rivers State, southeastern Nigeria.

Zone	Farming system	Number of standing leaves	Youngest leaf spotted	% Leaf area with symptoms
Meander belts	Homestead	10.0 c	7.8 c	11.9 a
	Field	8.7 b	6.0 b	16.2 b
Coastal plain sands	Homestead	9.0 b	5.9 b	16.3 b
	Field	6.5 a	4.0 a	22.8 c

Within columns, means followed by the same letter are not significantly different at $P < 0.05$, according to Duncan's multiple range test.

mulched plantain. The mulched plantain had a higher number of hands and fruits per bunch than the non-mulched ones (**Table 4**). Yield per hectare, calculated from the average bunch weight multiplied by plant density, of the best-performing plantain treated with rice husk was 46, 37 and 26% higher than those of control, cover-cropped and fertilized plantain, respectively. Soil fertility was the critical factor responsible for the differences between crop residues mulches, cover crop and fertilizer. Therefore, proper management of organic matter is essential for the sustainable productivity of plantain, by minimizing the BLS severity with low inputs.

West Africa

1. On-farm survey of BLS disease

In Nigeria, the southeastern region which is also located in the humid forest zone is the main plantain producing area (Martin 1979; Swennen 1990). In 1992, an on-farm survey was conducted in two different geomorphological zones of southeastern Nigeria: Meander belts in the central Niger delta area and Coastal plain sands in the East of the Niger delta. Field plantations and homestead gardens were selected in four villages of each zone and BLS severity was evaluated on 10 plants per location. The evaluation was based on percentage of leaf area with symptoms (Gauhl *et al.* 1993), the youngest leaf spotted (YLS) and the number of standing leaves (NSL).

Results presented in **Table 5** indicated that the Meander belt soils were richer in nutrients than those of Coastal plain sands. Soil fertility in Meander belt fields was comparable with that in Coastal plain sand homesteads. For each zone, soils in the homesteads were more fertile than in the fields, due to frequent application of household refuse and mulch which were sources of soil nutrients.

The BLS severity in Meander belt fields was similar to that in Coastal plain sand homesteads (**Table 6**). The lowest BLS severity was observed on plantain growing in Meander belt homesteads, while the Coastal plain sand fields showed the highest disease severity.

Disease severity was highly correlated with the selected soil chemical properties (**Table 7**). Climatic parameters recorded during the survey were similar in the two geomorphological zones and in the two farming systems (Mobambo *et al.* 1994a, 1994b). Therefore, the differences in the host response to BLS between Meander belts and Coastal plain sands and between field plantations and homestead gardens were mainly attributed to the differences in soil fertility. The higher the soil fertility level, the lower the BLS severity. On better soils this is expressed in a higher number of standing leaves, older leaves bearing dry spots and less leaf area with BLS symptoms (**Tables 1, 3-6**).

2. On-station evaluation of BLS disease over cropping cycles

In 1987, breeding for resistance to BLS started at IITA and new plantain hybrids were developed (Swennen and Vuylsteke 1993; Vuylsteke *et al.* 1993a; Vuylsteke *et al.* 1993b). From 1990 to 1993, a local French plantain 'Obino l'Ewai' (OL) was evaluated over two cropping cycles along with its derived tetraploid hybrids (TMPx) for BLS resistance. OL was planted in a fungicide-treated (FT) and non-treated (NT) plots.

Fungicide application, cultural practices, soil analysis and climatic data recording were as described earlier (Mobambo *et al.* 1993b). Both disease development (period between infection and appearance of spots with dry centres) and disease severity (percentage of leaf area with symptoms) were recorded.

Climatic conditions were similar over cropping cycles (Mobambo *et al.* 1996a, 1996b). Adversely, soil fertility de-

Table 5 Selected soil chemical properties under field plantations and homestead gardens in different geomorphological zones of Rivers State, southeastern Nigeria.

Zone	Farming system	pH (H_2O)	Organic C (%)	Total N (%)	Exchangeable cations (meq/100 g)		
					Ca	Mg	K
Meander belts	Homestead	6.8 c	3.79 c	0.29 c	8.45 c	2.00 c	0.97 c
	Field	5.7 b	2.00 b	0.18 b	3.26 b	0.76 b	0.33 b
Coastal plain sands	Homestead	5.7 b	2.14 b	0.17 b	6.21 c	1.04 b	0.72 c
	Field	4.3 a	1.17 a	0.10 a	0.61 a	0.22 a	0.16 a

Within columns, means followed by the same letter are not significantly different at $P < 0.05$, according to Duncan's multiple range test.

Table 7 Correlations between soil chemical properties and host response to black leaf streak of the False Horn plantain cv. 'Agbagba' under fields (F) and homestead (H) conditions in Rivers State, southeastern Nigeria.

Soil chemical properties	Correlation coefficients*					
	Number of standing leaves (n = 8)		Youngest leaf spotted (n = 8)		% Leaf area with symptoms (n = 8)	
	F	H	F	H	F	H
pH	0.875*	0.867	0.888	0.893	-0.895	-0.863
%OC	0.979	0.974	0.973	0.969	-0.971	-0.975
%TN	0.861	0.858	0.835	0.856	-0.845	-0.851
Ca	0.864	0.870	0886	0.866	-0.876	-0.874
Mg	0.871	0.873	0.875	0.886	-0.872	-0.873
K	0.907	0.971	0.876	0.896	-0.889	-0.972

*All r values are significant at the 0.01 probability level

Table 8 Selected soil chemical properties before planting, at flowering of plant crop and at flowering of ratoon crop at IITA-Onne station, southeastern Nigeria.

Cropping cycle	pH (H_2O)	Organic C (%)	Total N (%)	Available P (ppm)	Exchangeable cations (meq/100 g)			
					Ca	Mg	K	Na
Before planting	5.10	1.86	0.18	105.8	1.36	0.36	0.28	0.26
Plant crop	4.81	1.52	0.11	93.7	0.88	0.31	0.18	0.18
Ratoon crop	4.20	0.99	0.09	77.4	0.54	0.16	0.11	0.09
LSD* (0.05)	0.12	0.04	0.02	8.3	0.19	0.03	0.04	0.03

*LSD: Least significant difference

Table 9 Host response to black leaf streak of the plant crop (PC) and the first ratoon crop (RC) of three plantain hybrids (TMPx) as compared with their plantain (AAB) parent, cv. 'Obino l'Ewai' (OL), both fungicide-treated (FT) and non-treated (NT) at IITA-Onne station, southeastern Nigeria.

Clone	Symptom evolution time (days)		N° of standing leaves		Youngest leaf spotted		% Leaf area with symptoms	
	PC	RC	PC	RC	PC	RC	PC	RC
OL, NT	24.9	13.1	8.5	6.3	5.8	4.2	20.3	34.8
OL, FT	34.1	21.6	10.5	8.5	7.3	5.8	18.9	25.3
TMPx 597-4	51.8	42.5	11.0	8.0	9.1	6.8	6.4	12.2
TMPx 548-4	58.8	52.4	11.3	10.5	10.5	10.0	4.2	5.6
TMPx 548-9	61.4	44.5	11.8	10.0	10.7	8.7	3.8	7.8
LSD* 0.05[a]	7.6		1.4		0.8		1.3	
LSD 0.05[b]	8.1		1.6		0.9		1.5	

[a] LSD between clones for same crop cycle.
[b] LSD between crop cycles for same clone.
*LSD: Least significant difference

clined from the period before planting to the second cropping cycle (**Table 8**). During the plant crop (PC) the soil had higher nutrient levels than during the ratoon crop (RC). As pointed out by Lal and Kang (1982), under continuous cropping the soil degrades very rapidly, associated with a substantial decline in organic matter status.

BLS development was much faster in RC than in PC of both OL-NT and OL-FT (**Table 9**). Symptom development was 12-13 days faster and both YLS and NSL decreased by 2 leaves in RC of either NT or FT plantain. This indicated that despite the use of fungicide to prevent infection, the host response to BLS over cropping cycles was affected by the soil fertility decline in RC. However, the combined effects of fungicide treatment and cropping cycle demonstrated that the disease development on OL-FT/RC was similar to that on OL-NT/PC. The lowest BLS attack was observed on OL-FT/PC, while the highest was on OL-NT/RC.

The IITA tetraploid hybrids (TMPx 597-4, 548-4 and 548-9) evaluated along with their triploid plantain parent were reported as partially resistant to BLS (Mobambo *et al.* 1993b, 1994c).

YIELD LOSS ASSESSMENT

The most important yield components which influenced bunch weight both in the plantain parent OL and tetraploid hybrids (TMPx) were the weight, volume, length and girth of the fingers (Mobambo *et al.* 1993b, 1996a). Yield per hectare and cycle was calculated from the average bunch weight taking into consideration the percentage of lost plants (**Table 10**).

The reduction in functional leaf area of plantain by the fungus significantly affected yield. The loss in plantain yield due to BLS was 33% in PC and 76% in RC, as determined per cropping cycle from the difference in yield between the fungicide-treated and non-treated plantain plots (**Table 10**). In RC the incidence of pests (banana weevil and nematodes) was higher than in PC (Mobambo *et al.* 1996a). Over cropping cycles, yield decreased considerably in RC due to the high percentage of lost plants caused by the effects of BLS severity, soil fertility decline and pest attack as well as wind damage. The whole complex of disease, soil fertility decline and pests together reduced yield in plantain by 93%, as calculated from the difference in yield between PC of the fungicide-treated and RC of the non-treated plantain.

Yield decline from PC to RC was lower in TMPx than in their female plantain parent. It is inferred that host plant

Table 10 Yield of the plant crop (PC) and the first ratoon crop (RC) of three tetraploid hybrids (TMPx) as compared with their plantain (AAB) parent, cv. 'Obino l'Ewai' (OL), both fungicide-treated (FT) and non-treated (NT) at IITA-Onne station, southeastern Nigeria.

Clone	Bunch weight (kg)		Lost plants[a] (%)		Yield[b] (t ha^{-1} $cycle^{-1}$)	
	PC	RC	PC	RC	PC	RC
OL, NT	9.4	4.0	0	75	15.7	1.7
OL, FT	14.1	6.9	0	39	23.5	7.0
TMPx 597-4	7.6	6.3	0	17	12.6	8.9
TMPx 548-4	14.9	14.0	0	17	24.9	20.4
TMPx 548-9	20.0	15.2	0	25	33.3	19.0
LSD* 0.05[c]	2.1		1.4		0.8	
LSD 0.05[d]	2.2		1.6		0.9	

[a] No mean comparison (LSD) was performed on this parameter.
[b] Yield based on harvested area.
[c] LSD between clones for same crop cycle.
[d] LSD between crop cycles for the same clone.
*LSD: Least significant difference

resistance to the disease is one component of higher yield in plantain hybrids. However, their better performance in RC with higher yield compared with the fungicide-treated plantain suggested that BLS resistance was not the sole component of high yield, but that heterosis could also play an important role.

CONCLUSION

As a perennial starchy crop, plantain requires a considerable time to mature, resulting in longer exposure to diseases, pests and depletion of soil nutrients. Traditionally, it is a homestead crop in Africa where it can be produced for many years because of regular application of household refuse and other kitchen waste. In this environment disease severity is low and yield can be maintained over many years. Improving cultural practices appears to be the fastest, most feasible and most realistic approach for the sustainable productivity of plantain. Proper management of organic matter using several crop residues or planted fallow with trees/hedgerow species serving as a source of mulch would be very useful in reducing the effects of the disease-pest-soil fertility complex on plantain, as is the case in homestead gardens.

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