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Maize streak disease in Burundi highlands [1]

R.S. Zeigler*, W. Gashaka** and M. Kaybigi**

Résumé

En 1982, une forte extension de la "striure du maïs ou Mais Streak Disease (MSD)" fut observée sur les maïs plantés en saison sèche en zone de haute altitude (1.850 m) au Burundi. En 1983, la maladie prit de l'importance sur les maïs des hauts plateaux. Auparavant, la MSD n'était pas un problème dans ces régions. Les Cicadulina spp. *capturées sur les champs atteints par la MSD étaient essentiellement* C. storeyi *tandis que* C. mbila *était peu représentée. Dix pour cent des populations sauvages étaient les vecteurs actifs de la maladie cependant que dix-sept pour cent de celles-ci auraient pu transmettre le virus. Des variétés de maïs résistantes au MSD, reçues de l'IITA, furent testées entre 830 et 2050 m d'altitude. Elles se révélèrent résistantes à la maladie mais mal adaptées aux conditions d'altitude. L'intensification de la culture du blé dans les collines peut expliquer le développement de la MSD.*

Summary

In Burundi, beginning in 1982 high incidence of maize streak disease (MSD) was observed in high elevation (1850 m) bottomland maize planted during the dry season. In 1983 high levels of MSD were observed in high elevation upland maize as well. MSD has not previously been a problem in highland maize in Burundi. Cicadulina *spp. collected from MSD-affected fields were predominantly* C. storeyi *with* C. mbila *poorly represented. Ten percent of wild populations were active vectors, while 17% were capable transmitting the virus. MSD-resistant material from IITA was tested at 830 m and 2050 m and found to be resistant at both sites, but poorly adapted to the high elevation environment. Increasing wheat culture in the highlands may explain the increasing importance of MSD.*

1. Introduction

Burundi is a small, mountainous country in Central Africa. Elevations range from 770 m on the shore of Lake Tanganyika to over 2600 m along the Nile-Zaire Crest, resulting in a varied climate over relatively short distances. Soils are generally nutrient poor, acid oxisols. With 155 people/km^2 the country is the second most densely populated in Africa, yet depends almost entirely on traditional subsistence agriculture for its food needs. Average gross national product per capita is 180 USD/yr.

Maize is a principal dietary component and is their most important staple food in the high elevations (1850 m). Local maize is very heterogenous, exclusively open pollinated and grown from farmers' seed. The crop is usually interplanted with beans under very low input conditions on small parcels (0.5 ha). Inputs consist of human labor and composted residue or animal manure, if available. Maize yields vary greatly, but are estimated to average 1.5 T/ha.

The maize-bean system may be divided into two major subsystems: dry season bottomland planted in July-August and wet season upland planted in October-November. While plantings in bottomlands are often very small, (0.2 ha) and greatly inferior to upland in total area, they are nonetheless quite important since it is this production which enables the population to endure annual food shortages in November and December.

Maize streak disease (MSD) is caused by a leafhopper (*Cicadulina* spp.)-transmitted virus. Hosts include a wide range of graminaceous species (3). Symptoms first appear as small, isodiametric colorless spots on young leaves which elongate and coalesce to form cream-colored or white streaks. The virus systemically infects all subsequently developing foliage, while foliage mature before infection remains symptomless. Susceptible plants may exhibit complete chlorosis. Yield losses are dependent on time of infection, with very early infection resulting in substantially reduced yields (2,6). The disease is only known to occur in Africa, Réunion and India.

MSD has been known in Burundi for at least 30 years. Until recently it was only important in areas below 1200 m. There is no record of it ever being a problem in high elevation maize culture. In 1982 apparently unprecedented levels of MSD were

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* Pathologist, Rice Program, Centro Internacional de Agricultura Tropical (CIAT), AA 6713, Cali, Columbia, S.A.

** Maize-Pea Program, Institut des Sciences Agronomiques du Burundi, (ISABU), B.P. 795, Bujumbura, Burundi.

observed in high elevation bottomland fields and in 1983 severe outbreaks were observed in high elevation upland maize culture. In this paper we report on the distribution of MSD in the highlands of Burundi and on the results of evaluation of MSD-resistant material received from the International Institute of Tropical Agriculture (IITA) in Nigeria.

2. Materials and methods

Fifty adults of *Cicadulina* spp. were collected from maize fields with high levels of MSD, placed singly in small tubes and fed on young healthy maize plants for 48-72 hours to determine vector frequency in wild *Cicadulina* populations. Individuals were then fed on MSD-affected plants for 48 hours, and placed on other healthy maize plants to establish the potential transmission level. Males collected from the field and males progeny of collected females (50 in total) were sent to D.J.W. Rose (Commonwealth Institute of Biological Control, Kenya Agric. Res. Inst., Nairobi) for species identification.

A preliminary survey was conducted in the high elevation areas of the country in late 1983 to establish MSD severity. Those areas with high MSD incidence were surveyed in more detail. For both heavily affected and lightly affected heighboring plots data were taken on percent attack (plants per plot and plots per field), varieties planted, planting dates, stages of maize at infection, and MSD levels in previous years. This was undertaken for both bottomland and upland conditions. Since almost all the local maize is highly susceptible, the severity of symptoms and yield loss for a particular plant are merely a function of time of infection, severely limiting information available on yield impact.

Eight varieties with MSD resistance (SR) were received from IITA. Six of the varieties (Across 7729 SR, Tlaltizapan 7729, Poza Rica 7822 SR, Across 7728 SR, Tocumen SR and Poza Rica 7843 SR) were the fourth back cross from crosses of CIMMYT experimental varieties and IITA SR material. The remaining two were IITA white and yellow varieties, TZSRW and TZSRY. These varieties, four susceptible checks (GPS 4 x SR 52, Tlaltizapan 7844, Poza Rica 7822 and Katumani) and one tolerant variety from Zaire (GPS 5) were planted at the "Institut des Sciences Agronomiques du Burundi (ISABU)" experiment station on the Imbo plain (830 m) near the end of the rainy season in May 1983 when lowland maize usually experiences high levels of MSD. The varieties were planted at a density of 53000 plants/ha in plots 2.25 x 5 m, separated by 1 m, replicated four times in randomized blocks. Within the 1 m alleys were planted rows of a susceptible CIMMYT experimental variety, Ferke 7643. When this susceptible material showed substantial symptoms of MSD (5 weeks after planting) all plants in the alleys were cut down to drive viriliferous vectors into adjacent plots. Weekly for eight weeks after emergence the number of plants showing moderate to severe MSD symptoms were counted for each plot.

At flowering, varieties were evaluated for the level of MSD attack using the following scale: O = symptomless; 1 = widely separated small streaks primarily on lower leaves; 2 = widely separated small streaks distributed over whole plants; 3 = larger streaks more densely distributed but not coalescing to from chlorotic patches, at least at the bases of affected leaves; 5 = near total chlorosis of affected leaves, premature tasseling and/or plant death. The MSD level of a plot was taken as the highest MSD level of the 20% most severely affected plants to avoid including escapes in the evaluation. This prevented the rare plant showing moderate MSD symptoms in the otherwise low MSD level plots of the SR converted experimental varieties from being considered representative, since after only 4 back crosses there was more than likely still some segregation for resistance taking place.

The six SR converted experimental varieties, one improved local variety (Igarama 4) and farmers' local maize were planted in farmer fields near Kisozi (2050 m) in the bottomland season, July 1983. The area chosen had a severe attack of MSD in the 1982 season. The varieties were planted in single rows separated by 75 cm with 50 cm between hills. Each row of SR material was separated by a row of susceptible local material. Planting of trial coincided with farmer planting and was replicated four times in the bottomland. Because of the small size of farmers' plots, all the varieties used in the lowland trial could not be planted in the highland trial and plot size for each variety had to be reduced to one row.

After flowering the plants showing symptoms were grouped in the classes of the above described rating scale. Assessment of MSD levels in plots are based only on diseased plants since symptomless plants were considered to be escapes.

For the Imbo trial the number of plots in each MSD class and for the Kisozi trial the number of plants in each MSD class were subjected to a 2(SR - non SR) x 5(MSD classes 1 - 5) contingency table analysis using a χ^2 test for the nul hypothesis of no diffence in distribution over the MSD scale between SR and non-SR. For both trials, analyses of variance with appropriate planned comparisons using orthogonal coefficients to partition treatment sums of squares were conducted on number of diseased plants with MSD rating 3 or more.

3. Results and discussion

3.1. Vector transmission

Adult *Cicadulina* collected from the field and their progeny were determined to be *C. storeyi* and *C. mbila*, with the former representing 98% of the individuals sent for identification. Ten percent of the individuals from the field directly transmitted the virus to the test plants, while after feeding on MSD-affected plants and incubation 17% of the individuals transmitted the virus. Thus, even where there is an MSD epidemic, perhaps only 10% of *Cicadulina* individuals are active vectors and only 20% of the wild population may be capable of transmitting the virus. Similar levels of transmission were found for *Sogatodes oryzicola*, vector of the hoja blanca virus of rice, during an epidemic of that disease in Colombia, South America (1).

3.2. MSD distribution

In 1982, severe attacks of MSD were found to be limited to bottomland production along the Nile-Zaire Crest at elevations from 1850 - 2200 m. The most severely affected areas were near Kayanza, Kiganda and Kisozi (Fig. 1). MSD was distributed unevenly within and among stream valleys with some having MSD incidence greater than 80% while adjacent valleys had less than 10%. Within bottomland plantings MSD incidence varied widely, exceeding 90% within 50 m of plots with MSD incidence of less than 20%. High incidence plots were usually along the edges of the stream valleys or early plantings.

In the 1983 bottomland season many stream valleys with high 1982 MSD incidence had very low incidence (less than 5%) while others continued to be high.

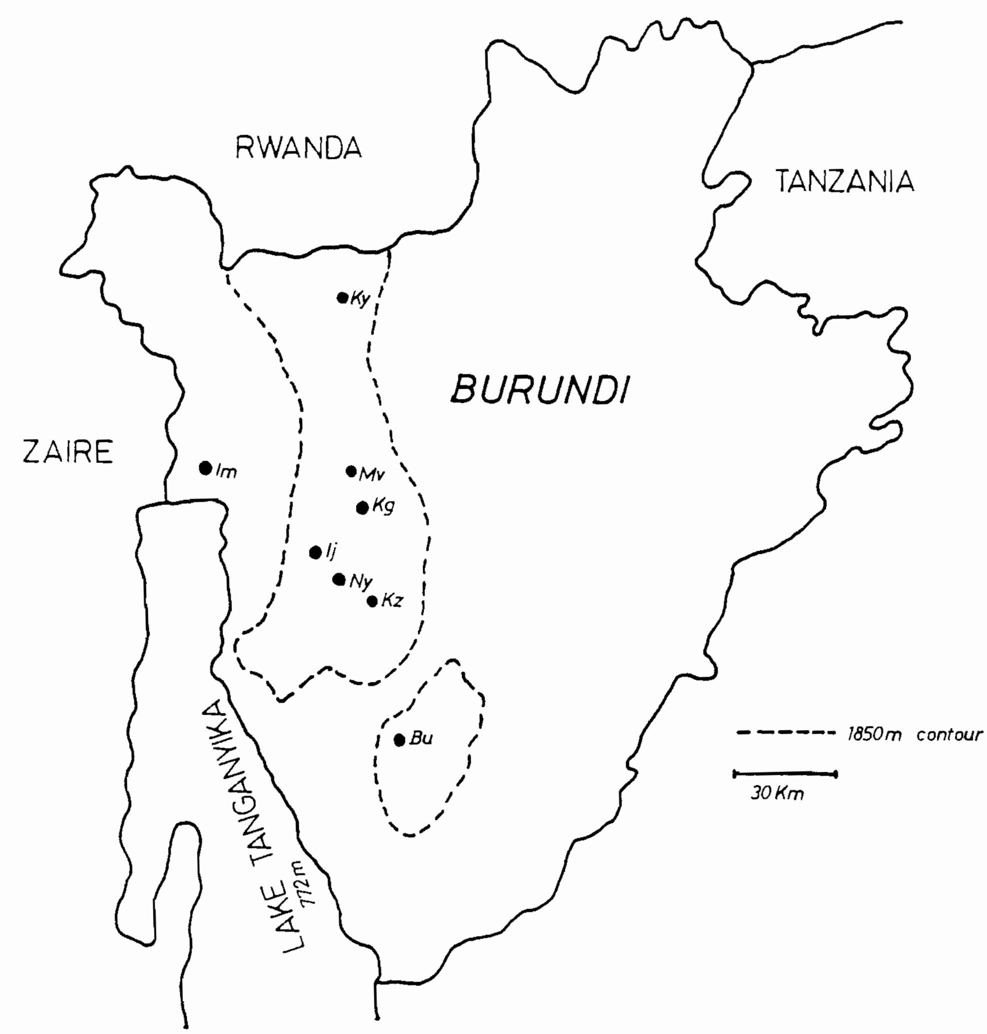

Figure 1 : Map of Burundi showing sites relating to discussion of MSD outbreak in Burundi highlands.
Bu = Bururi, Ij = Ijenda, IOm = Imbo, Kg = Kiganda, Ky = Kayanza, Kz = Kisozi, Ny = Nyakararo, Mv = Muramvya.

Year to year variability in MSD incidence in the field is common and has been a factor limiting the development of MSD-resistant varieties (5).

In 1983 a severe outbreak of MSD was observed in upland maize near Muramvya, Kiganda, Kisozi and Ijenda. Fields with at least 99% incidence were common in some localities and inoculation for the majority of plants occured at the 3-5 leaf stage. Since inoculation of the susceptible material at a very young age can result in losses approaching 100% (6) these fields may be considered to be total losses. Bottomland maize adjacent to seriously affected hillsides usually showed relatively low incidence of MSD. Around Bururi, at the southern extreme of the highlands (Fig. 1), very little MSD was observed. The most seriously affected upland plots there had MSD incidence of less than 20% with most plots having no diseased plants.

Distribution of MSD in high elevation was quite irregular. MSD was present in approximately 75% of bottomland maize plots surveyed, and the range of infected plants per plot in some stream valleys was from 5 - 25% while in others 50 - 80%. MSD was present in only 25% of upland plots sampled; however, plots with more than 99% MSD were frequently found among those. There was no relationship detected with associated inter-crops or maize variety and MSD incidence. Almost all the heavily affected upland plantings were planted in early August when there was a brief and unusual rainy period.

Interviews with elderly farmers and expatriate agronomists familiar with maize cultivation in the area over the past 30 years indicated that these are the first years in living memory that MSD has been a problem in high elevation maize. No farmer had ever seen such levels of MSD and all said that they first noticed the disease one or two years before the epidemic. At that time they noticed only a few diseased plants per plot. Since maize probably arrived in Burundi around 1900 (3) it may be that the pathogen has only just reached the Burundi highlands. However, it is not clear why it has taken so long to reach the highlands from the lowlands (a distance of less than 50 km) when the disease has been present in the lowlands for decades.

In Zimbabwe, Rose (4) has described a close relationship between maturing "winter" cereals and MSD on nearby maize. The epidemic in the Burundi highlands may have been a result of a combination of early maize planting and neighboring dry season wheat culture. Instead of the usual continuous dry season from late May through mid-September a heavy rain fell during the first week of August. Farmers who had already prepared their fields planted their maize for an early crop. Maize emergence coincided with ripening of late wheat planting. As wheat is a host to both *Cicadulina* spp. and the MSD virus, viriliferous vectors may have left the wheat and fed on adjacent young maize plants during their dispersal. With the recent construction of a flour mill in Muramvya, highland areas planted to wheat have increased markedly. Around Burundi and in the medium elevations, where wheat is not grown in appreciable amounts, MSD has yet to be a serious problem. Thus, wheat may serve as a "bridge" over the dry season by maintaining high *Cicadulina* populations. If this hypothesis is correct, MSD will probably continue to be a problem in the Burundi highlands. It is impossible to assess the impact on maize yields of the highland MSD outbreak on a national level. Given that almost all the affected maize is grown by subsistence-level farmers for home consumption or local sale, the losses are probably best considered on an individual level. In some areas personal losses likely approached 100% of the expected yield. Indeed, farmers around Muramvya destroyed their affected maize to replant their fields with sweet potatoes. If MSD incidence continues to rise in the highlands, nutrition on a regional basis, at least, may be adversely affected.

3.3. Field evaluations of SR material

The results of the field evaluation of the SR material from IITA are presented in Table 1. A11 SR converted varieties showed a very high level of resistance to the MSD virus in both high and low elevations. GPS 5 also showed an intermediate level of resistance in the lowland trial. Mean squares from analyses of variance on the number of plants diseased (expressed as percent in Table 1) are presented in Table 2. Partitioning treatment sums of squares for orthogonal comparisons showed that there are very significant differences between SR and non-SR groups at both sites. At Imbo no significant differences were observed between IITA SR varieties and SR-converted CIMMYT experimental varieties or within IITA varieties. GPS 5 was found to differ significantly from the other check varieties, which is consistent with observed intermediate resistance in earlier trials. Yield data are not available due to irrigation failure after flowering.

The contingency table (Table 1) gives a χ^2 of 45.2 and 133.5 for Imbo and Kisozi, respectively, leading at both sites to a rejection of the hypothesis that the MSD rating distribution is not different for SR and non-SR varieties.

TABLE 1
Performance of MSD — resistant and susceptible maize varieties at two elevations in Burundi

Variety a	Imbo (830 m)						Kisozi (2050 m)					
	% Plants[b] MSD≥3 at 8 wks[c]	No Plots with MSD rating[c]					% Plants[b] MSD≥3 at 14 wks[c]	No. Plants with MSD rating[c]				
		1	2	3	4	5		1	2	3	4	5
Across 7728 SR (CC)	10.0	4	0	0	0	0	5.0	16	1	2	0	0
Across 7729 SR (CC)	10.5	4	0	0	0	0	7.5	15	2	2	0	0
Poza Rica 7843 SR (CC)	13.5	4	0	0	0	0	0	9	0	0	0	0
Poza Rica 7822 SR (CC)	9.8	4	0	0	0	0	14.0	8	5	1	1	0
Tlaltizapan 7844 SR (CC)	12.0	3	1	0	0	0	2.5	21	3	1	0	0
Tocumen 7835 SR (CC)	9.8	4	0	0	0	0	0	9	0	0	0	0
TZSR Y (IC)	13.8	4	0	0	0	0	—	—	—	—	—	—
TZSR W (IC)	19.0	4	0	0	0	0	—	—	—	—	—	—
GPS 5 (SS)	25.2	0	1	2	1	0	—	—	—	—	—	—
Tlaltizapan 7844 (SS)	35.3	0	0	1	3	0	—	—	—	—	—	—
GPS 4 X SR 52 (SS)	51.1	0	0	0	3	1	—	—	—	—	—	—
Katumani (SS)	57.5	0	0	0	0	4	—	—	—	—	—	—
Igarama 4 (SS)	—	—	—	—	—	—	25.0	0	0	1	15	6
Isega (SS)	—	—	—	—	—	—	36.0	0	0	1	16	10
LSD (p = 0.05)	12.1 d						18.6 d					
Tabular χ^2 (d.f. = 4)						13.3						13.3
Observed χ^2	45.2**						133.5**					

[a]CC = CIMMYT experimental variety converted to SR;' IC = IITA variety converted to SR; SS = varieties not converted by IITA to MSD resistance (in GPS 4 × SR 52, SR does not correspond to MSD resistance).

[b]% of total plants in plots for ease of comparison between sites; analyses performed on counts; — = variety not in trial; ... = analysis was not applied; ** = p≤0.01

[c]MSD scale. 0 = symptomless; 1 = widely separated streaks limited to lower leaves; 2 = widely separated streaks over whole plants; 3 = large streaks more densely distributed but not coalescing to from patches; 4 = long streaks coalescing to from chlorotic patches, at least at base of leaves; 5 = near total chlorosis of affected leaves, premature tasseling and/or plant death.

[d]based on analysis of counts and converted to %.

TABLE 2
Mean squares for analysis of variance of number of plants with MSD≥3 in MSD resistance trials planted at two sites in Burundi

Source[a]	df	MS[c]	Source[a]	df	MS[c]
Total	47	23.9	Total	31	11.2
Repetition	3	3.1	Repetition	3	12.6
Treatment	11	887.5**	Treatment	7	27.5**
SR vs SS[b]	1	2530.0**	SR vs SS[b]	1	160**
CC vs IC[b]	1	49.0	Within SS[b]	1	10.1
TZRS w vs			Error	21	5.5
TZRS y[b]	1	14.3			
GPS 5 vs			14.3		
other SS[b]	1	408.1**			
Error	33	45.0			

[a]SR = IITA converted varieties with MSD resistance; SS = non converted material; CC = converted CIMMYT experimental varieties; IC = converted IITA varieties; GPS 5 = non-converted variety from Zaire observed to be tolerant before these experiments

[b]planned comparisons using orthogonal coefficients to partition treatment sum of squares into components of interest

c** = significant at p≤0.01

Unfortunately the SR material was very susceptible to common rust caused by *Puccinia sorghi*, and very poorly adapted to the high elevation conditions. Thus, to convert high elevation material to SR will require a lengthy back-cross procedure. An alternative to back-crossing SR resistance into local material would be to identify resistance in well adapted local material for immediate improvement. Indeed such seemingly resistant plants have been found in local populations at a frequency of between 1·10³ and 1·10⁴. Typically they show MSD symptoms on all leaves but instead of the lesions coalescing to cause total leaf chlorosis they remain small, narrow and widely separated. Studies are underway to evaluate the heritability of this promising characteristic and the feasibility of rapidly creating improved resistant locally-adapted varieties.

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R.S. Zeigler: American, Ph D. (Plant Pathology) International Development Research Centre (Ottawa, Canada)

W. Gashaka: Burundi, Ingénieur agronome: ISABU.

M. Kaybigi. Burundi, Ingénieur agronome. ISABU.