ASSESSMENT OF MAIZE LETHAL NECROSIS (MLN) PREVALENCE AND ITS IMPACT ON MAIZE PRODUCTION IN RWANDA

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Abstract

Maize lethal necrosis (MLN) is a serious viral disease of maize, which was first reported in Rwanda in 2013. Being aware of the disastrous effects it had caused in regional countries, we set out to study its prevalence, level of awareness among farmers on management practices and its impact on the overall maize production and farmer livelihoods during 2015. This country wide study targeted a total of 539 respondents drawn from all the 30 districts, down to each sector. We used stratified, purposive and random sampling to collect data. Our results indicated a wide spread of disease to the entire country. We ran cumulative logistic regression models and found out that the chances of having higher levels of MLN in Western Province, for example, are ten, three, one and one times the chances in the Eastern Province, Kigali, Northern Province and Southern Province, respectively. Results also showed that a significantly higher number of respondents (54.4%) were not aware of MLN, which is a concern for its management. The assessment of MLN impact on maize production indicated that the disease had caused losses of up to 100% and was threatening the production of this food security crop. The observed low levels of MLN awareness as well as inappropriate plant protection measures calls for stepping up of MLN awareness and management campaigns among the farming community to curtail its further spread.

Key words: Maize lethal necrosis, Rwanda, prevalence, impact

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Introduction

Maize (*Zea mays* L.) is an important food security crop in Rwanda, which ranks first among grain crop production. Maize production has been steadily increasing since 2007, when the government adopted an intensification program for the crop. This crop is actually regarded as the most important staple in Sub-Saharan Africa, which takes a"lion's share" of the five crops that account for 45% of the total crop production in the region (FAO, 2016).There still remains a huge unexploited potential for increasing maize production, not just in Rwanda but the entire Sub-Saharan Africa.However, the crop productivity in the Eastern Africa region and, specifically, Rwanda, is being threatened by a serious recent outbreak of a viral disease. This disease was first observed in the volcanic highlands of the country in February, 2013, which was later confirmed to be Maize Lethal Necrosis (MLN) (Adams *et al*., 2014). The disease is primarily caused by a dual combination of Maize Chlorotic Mottle Virus (MCMV), which is the principal virus, and a potyvirus (Uyemote *et al*., 1981). The widely known potyviruses that have been linked to MLN are Sugarcane Mosaic Virus (SCMV), Wheat Streak Mosaic Virus (WSMV) and Maize Dwarf Mosaic Virus (MDMV).

The MLN disease was first identified in the Eastern Africa region as an outbreak in Kenya in 2011 (Wangai*et al*., 2012b). It has since spread to other regional countries like Rwanda, Democratic Republic of Congo, Uganda, Tanzania, South Sudan and Ethiopia (Mahuku *et al*., 2015). Its origin can be traced in Kansas, United States of America, where it was first identified as Corn Lethal Necrosis (CLN) in 1977 (Niblett and Claflin, 1978). The most common form of MLN in the Eastern Africa region is a result of a dual combination of MCMV and SCMV, which is endemic in the region. Although MLN has seriously affected maize production in the Eastern Africa region, albeit at poorly known proportions, scanty information currently available has limited our understanding of the socio-economic effect the disease has had on the farming communities. This, coupled with the fact that it is a new and poorly understood disease, may severely negatively affect maize production in the region. In 2015, we conducted a comprehensive country wide MLN survey in Rwanda covering all the districts aimed at understanding the disease prevalence and its potential socio-economic impact on farmers. Data presented here, the first of its kind in Rwanda, indicates to what extent the disease has spread in the country, farmer practices of direct relevance to MLN development and spread, disease awareness levels as well as management aspects, among other things.

Materials and Methods

Field survey

In order to gather information on MLN prevalence, awareness levels, management and socio-economic impact on the maize farming communities in Rwanda, among other things, we used a semi-structured questionnaire to conduct a field survey across the entire country. Specifically, the key areas the survey covered include, but not limited to, household demographics, MLN incidence level, farmers' awareness and farming practices as well as effect on maize production and productivity. Furthermore, the geographical positioning of the survey sites was established mainly to help in disease mapping. The survey was carried out for a whole month of July 2015.

Sampling

This survey, which targeted a total of 539 respondents, covered all the 30 districts, down to all the 416 sectors of Rwanda. In each sector, we covered three households, and for a better geographical coverage, a minimum of five km was left between two respondent households. Stratified, purposive and random sampling techniques were used to select respondent households, depending on complexities of agro-ecological zones and maize coverage, among other things.

Data collection

Data was collected using a semi-structured questionnaire, and this was facilitated by scientists and technicians previously trained on MLN and its management. This was based on face to face interviews with respondents. In most cases, the data on MLN disease provided by respondent households was verified through seeking information on the disease history in the community and validated by field observations.

Data processing and analysis

Datasheets, earlier designed to accommodate all the important information from the survey, were used to record data in formats that are amenable to different downstream analyses. Data processing also involved harmonization of data collected by different enumerators. The cleaned database was then exported to the Statistical Package for Social Sciences (SPSS) software for further analysis. Different datasets and/or factors were compared by subjecting them to correlation, chi square test of independence and cumulative logistic regression methods of data analysis. This allowed us to discern determinant factors and their interaction in the MLN development and spread as well its socio-economic impact on farmers, among other things.The Global Positioning System (GPS) coordinates for sampled sites were used to generate national MLN maps. This was done by using the Aeronautical Reconnaissance Coverage Geographic Information System (ARC GIS) version 9.3 software.

Results and discussion

MLN prevalence in Rwanda

This study showed that in just a couple of years since MLN was first reported on a few maize plants as a localized infection in Musanze in 2013 (Adams et al. 2014), it had quickly spread to the entire country, albeit at different incidences from region to region. This is supported by the MLN prevalence map (Figure 1) and MLN incidence map (Figure 2) generated. The maps indicated that MLN is more prevalent in the north, west and south. We ran cumulative logistic regression models on this and found out that the chances of having higher levels of MLN in Western Province, for example, are ten, three, one and one times the chances in the Eastern Province, Kigali, Northern Province and Southern Province, respectively. This implies that Western, Northern and Southern provinces are equally affected by MLN while Eastern Province and Kigali are less affected.

The study further revealed that the highest levels of MLN incidence are found in the volcanic highlands situated in the north of the country. This is not surprising since we first observed MLN-like symptoms here early 2013 (Asiimwe *et al.*, unpublished data), specifically at Byangabo site, Busogo sector, Musanze district, which was later confirmed to be MLN (Adams et al. 2014). This region is now regarded as MLN hotspot. Throughout the whole country, field symptoms observed on infected plants in respondents' fields were similar to those described for MLN by Wangai et al. (2012b). These field observations by MLN experts, in many instances, were in agreement with the data on MLN prevalence and its history collected from respondents, which unequivocally validates the disease maps generated.

Knowledge on MLN and its management

Awareness of MLN is the single most important factor when it comes to its management. Our assessment of the disease awareness levels in the country revealed that the majority of farmers (54.4%) are not aware of MLN (data not shown). Generally, awareness levels are higher in places where MLN incidence is high (Figure 3). In fact, correlation modeling indicated that awareness of MLN is highly significantly ($p<0.01$) related to MLN incidence. This probably implies that MLN awareness interventions were carried out before, especially in places where the disease is more prevalent. The majority of farmers indicated that they started observing MLN in their fields around 2013 (data not shown), which is in agreement with our earlier observations.

Related to this, when farmers' opinion was sought on what could be the cause of MLN spread, the majority said that it could be transmitted through seed (data not shown). They indicated that MLN started showing up when hybrid seeds were introduced in their communities. This agrees with our observations on MLN historical data that it could have entered the country with imported hybrid seeds. Our field and screen house experiments indicated that MCMV, the principal MLN virus, can be transmitted from parents to offsprings for about three generations (Asiimwe *et al.*,unpublished). Transmission of MLN through seed, although it remains relatively unclear, has been reported before (Jensen, *et al.*, 1991; Maule and Wang, 1996; Mahuku *et al.*, 2015). Authors seem to disagree on the rate of seed transmission, but even low rates are enough to spread the disease through vectors such as thrips, which we observed in MLN-infected fields. Interviewed farmers seem to agree with this assertion since they indicated that once they observe MLN in their fields for the first time, the incidence increases rapidly in the coming days and seasons.

A range of MLN management options are being practiced by farmers, especially in endemic areas. The majority of famers (70.4%) indicated that they rogue out infected plants in the maize fields (Figure 4). However, a significant proportion of respondents indicated that they do not carry out any management option, and most of them never practiced the most important management options from the epidemiological point of view like avoiding continuous maize cropping. Our field observations confirmed this. Thus, the relatively high levels of MLN awareness in endemic areas reported here only seemed to refer to the disease, but not its management. Use of cultural practices for managing MLN, though not well documented in the Eastern Africa region, helps to slow down the disease. Our field observations as well as data from other authors (Nelson et al., 2011) confirmed this. Crop rotation, which we have indicated to be difficult to effectively implement due to the small land holdings in Rwanda, was proved to be effective in managing MCMV in central United States (Philips et al., 1982; Uyemoto, 1983). The best control strategy for MLN is going to be combining plant host resistance and cultural practices. For now, there is no resistant germplasm that has been reported, although tolerant lines are being developed.

Maize production practices of direct relevance to MLN development and spread

The majority of households (77.6%) grow maize on less than 0.5 Ha yet 64.6% indicated that maize was their main crop. This leaves farmers with no much freedom of choice to effectively rotate maize with other crops or practice fallowing. For example, only 7% of respondents indicated that they practice fallowing and 51.4% mix maize with other crops season after season. Epidemiologically, this forms a perfect environment for MLN development and spread. While it is rare that viruses get transmitted through soil, it has been suggested that MCMV can be transmitted this way. Mahuku et al. (2015) observed that

MCMV was detected in nearly 70% of the emerging seedlings planted into contaminated soil. This can get worse when maize crop debris is not removed from field after harvesting, which is a common practice we observed.

Figure 1: Prevalence of Maize Lethal Necrosis (MLN) disease in Rwanda. The map was generated by using the Aeronautical Reconnaissance Coverage Geographic Information System (ARC GIS) version 9.3 software. Red and green dots represent sites where MLN is present and absent, respectively

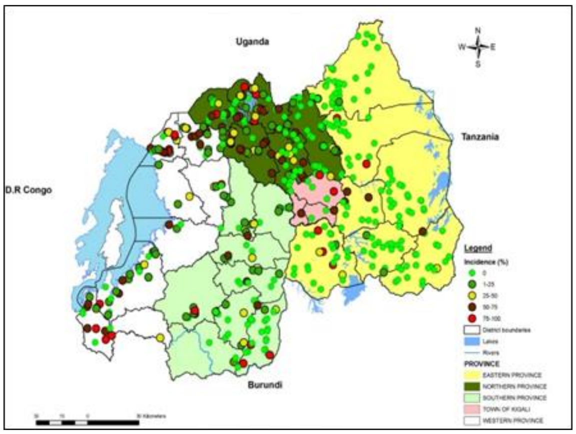

Figure 2: Incidence of Maize Lethal Necrosis (MLN) disease in Rwanda. The map was generated by using the Aeronautical Reconnaissance Coverage Geographic Information System (ARC GIS) version 9.3 software. Colors of the dots reflect incidence levels in percentages: Light green, absence of MLN; dark green, 1-25% incidence; yellow, 25-50% incidence; brown, 50-75% incidence; and red, 75-100%.

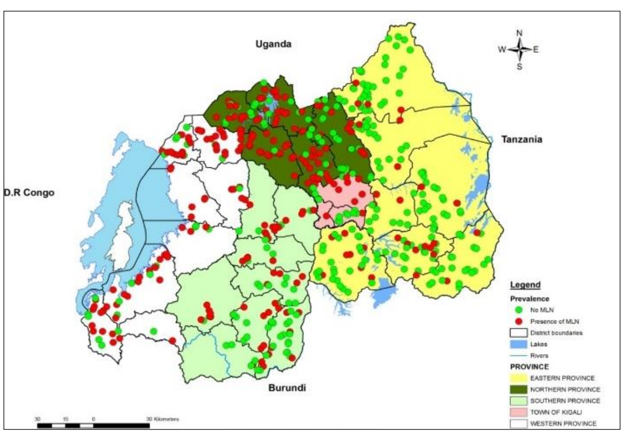

Figure 3: Awareness of Maize Lethal Necrosis (MLN) among farmers in Rwanda. Graphs were generated by using Statistical Package for Social Sciences (SPSS) software. Numbers on top of bars represent percentage

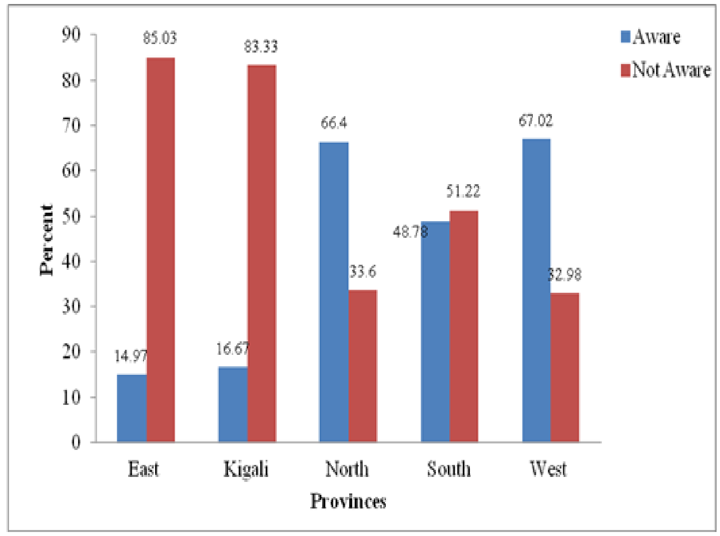

Figure 4: MLN management practices that have been carried out by farmers. Graphs were generated by using Statistical Package for Social Sciences (SPSS) software. Numbers on top of the bars represent the percentage of respondents practicing the respective disease management practices.

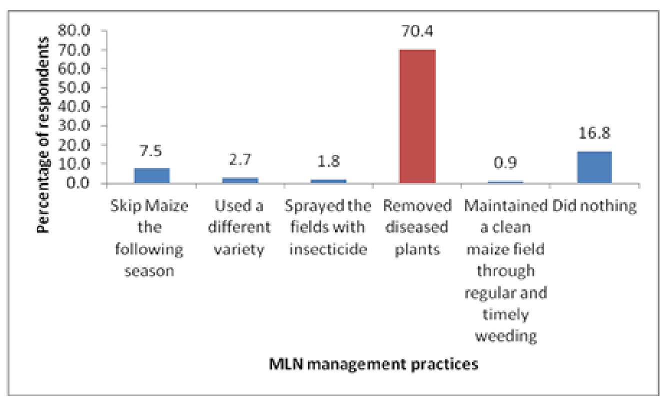

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Figure 5: Forms in which farmers sell their maize produce. Graphs were generated by using Statistical Package for Social Sciences (SPSS) software. Numbers on top of the bars represent the percentage of respondents indicating that they sell maize in a particular form.

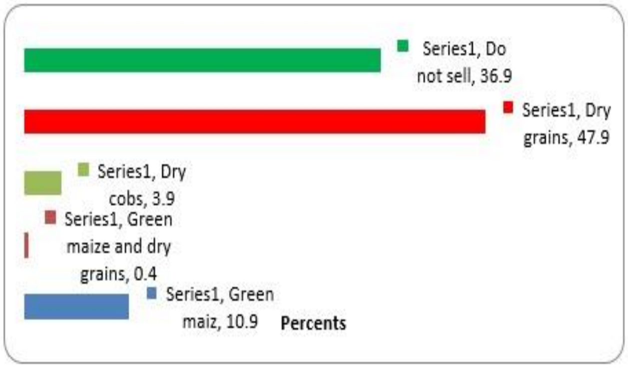
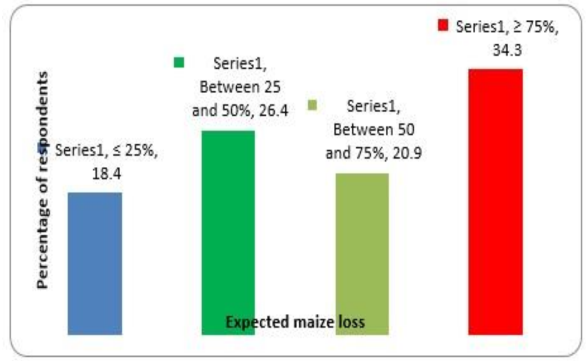


Figure 6: Expected grain loss from MLN-infected maize plantations as reported by farmers. Graphs were generated by using Statistical Package for Social Sciences (SPSS) software. Numbers on top of the bars represent the percentage of respondents reporting maize grain loss.



There are other notable farmer practices that could be responsible for the quick spread of MLN to non-endemic areas and recurrence in endemic ones. For example, a significant number of famers sell green maize; others sell cobs that are not properly dried (Figure 5). Furthermore, farmers tend to carry fresh maize plants for livestock feeding over long distances and carry out relay maize planting in their fields. All these practices that deal with fresh or partially dried maize plants or plant parts specifically pose a risk of transmission of MLN through vectors. There is also a risk of seed transmission since a significant number of farmers (36.4%) do not have access to certified seed; they use their own saved seed.

Our field observations indicated the presence of grasses growing as weeds in maize plantations. These, together with napier grass, which farmers grow on field boundaries for livestock feeding, can act as reservoirs for MLN viruses, especially MCMV (Bockelman et al., 1982; Mahuku *et al.*, 2015). There are other alternative hosts that some farmers use to do rotation with maize like sorghum yet it is, just like some other cereals, also infected with MLN viruses and acts as their reservoir. Although dicots have not been indicated to be infected by MCMV, the virus has a broad host range, including several grass species (Bockelman *et al.*, 1982).

Effect of MLN on maize production and socio-economic status of farmers

In MLN-affected areas, farmers indicated that they have been incurring maize grain losses due to the disease. From their past experience, they reported a yield loss of up to 100%. The majority of them expected more losses from their infected fields when this study was being conducted (Figure 6). Farmers indicated that this disease has severely affected their socio-economic status since they regard maize as the most important crop not just for food but for income generation as well. Elsewhere, MLN has equally been reported to be associated with huge maize grain and income losses. In Kenya, for example, the disease has been causing an estimated yield loss of 30-100% (Makone *et al.*, 2014; Mahuku *et al.*, 2015). In 2012 alone, 77,000 Ha were affected translating into an estimated yield loss of 126 million metric tons valued at U.S. $52 million (Wangai *et al.*, 2012a). Although economic losses have not been estimated in Rwanda, they are expected to be high since maize is one of the most important crops in the country; it is also one of the few crops on the Government of Rwanda's input subsidy program.

Conclusion

We have, for the first time, documented the prevalence of MLN as well as its impact on maize production and livelihoods of farmers in Rwanda. Our findings indicate that the disease, which was first observed as a new epidemic in 2013, has already spread to the entire country with disastrous effects where it occurs. The low MLN awareness levels observed in the country calls for stepping up of the disease awareness and management campaigns, especially in non-endemic areas for preventive purposes.

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