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Maize lethal necrosis disease: Evaluating agronomic and genetic control strategies for Ethiopia and Kenya

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ABSTRACT

Maize lethal necrosis disease (MLN) was first diagnosed in eastern Africa in the 2010's and is a big threat to their maize-based agri-food systems with estimated losses amounting to US$261 million in Ethiopia and US$198 million in Kenya. This paper reviews the agronomic and policy options to contain MLN and comparatively analyzes the feasibility of using maize-bean rotations and MLN-tolerant germplasm as key alternative strategies for managing MLN. Results from crop simulation and economic surplus models are used to make assessments on what strategy offers the most realistic MLN control approach given the circumstances of smallholder production in Kenya and Ethiopia. The paper finds that although maize-legume rotations are sound agronomic recommendations and are crucial for long term maize production system viability, their widespread application over large geographic areas for MLN control is economically challenging given that maize is a preferred staple. We conclude that scaling MLN-tolerant germplasm proves highly viable with estimated multiplier benefits of US $245-756 million in Ethiopia and US$195-678 million in Kenya, and benefiting up to 2.1 million people in Ethiopia and 1.2 million in Kenya. Given that the threat of MLN is present and ongoing, the food and economic security of maize-based agrarian economies in eastern Africa will critically depend on the successful mainstreaming of MLN tolerance in their maize seed systems.

1. Introduction

Maize lethal necrosis disease (MLN) is a new virulent maize disease in eastern Africa, first confirmed in Kenya in 2010 and subsequently spreading to neighboring countries. The region's reliance on maize-based agri-food systems and the susceptibility of prevailing (pre-2010) germplasm and conducive crop management has led to serious concerns about future MLN outbreaks for the maize sector, food security, livelihoods and economies of the region. MLN is a disease that results from the synergistic interaction of and infection by a virus belonging to the Potyviridae, such as Sugarcane Mosaic Virus (SCMV), Maize Dwarf Mosaic Virus (MDMV) or Wheat Streak Mosaic Virus (WSMV), and a virus belonging to the Tombusviridae, Maize Chlorotic Mottle Virus (MCMV) (Niblett and Clafin, 1978). MLN can have a devastating impact on maize grain yield, with losses of 23–100% in some affected plots in Kenya. The region's maize sectors have to implement practices, policies and deploy resistant maize varieties to help deal with this threat. In 2012 for example, 26,000 ha of maize were affected by MLN in Kenya with estimated losses of up to US$52 million (MoA, 2012) and by 2013 De Groote et al. (2016) estimated that the aggregate national loss of maize production due to MLN was about 0.5 million tons with a value of US$180 million. While similar analyses have not been produced for Ethiopia, the impact of MLN on the country's seed sector in particular and maize sector in general has raised serious alarms at high levels (Fentahun et al., 2017). The disease remains a present and ongoing threat to the maize sector in Kenya and the wider eastern African region (Isabirye and Rwomushana, 2016), with MLN already having been reported in Tanzania, Uganda, Rwanda, Burundi and Ethiopia.

Studies during 2012–13 confirmed that nearly all commercial maize varieties (approximately 98%) in Kenya were susceptible to MLN, both under natural disease pressure as well as under artificial inoculation (CIMMYT and IITA, 2014; Prasanna et.al., 2015). The maize seed systems in eastern Africa need to quickly replace these highly vulnerable varieties. Subject to technical, economic and social analyses to guide the most effective actions, the public and private players need to, *inter alia*, invest in i) ensuring a strong pipeline of maize products with

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resistance/tolerance to MLN coupled with other important adaptive traits (e.g., drought tolerance); and ii) accelerating scale-up and delivery of MLN-tolerant maize varieties. The reported genetic vulnerability of most maize varieties to MLN however raises further questions about what additional interventions including agronomic practices such as crop rotations (to create maize free windows) can minimize the effects of MLN on the maize-dependent agri-food systems and seed sectors and accelerate mainstreaming of MLN-tolerant varieties.

Using the case of Ethiopia and Kenya, the overall aim of this paper is to analyze the expected feasibility of two MLN control strategies: (1) using crop rotations, particularly maize-free windows involving maize-bean rotations, and (2) mainstreaming MLN-tolerant germplasm. The contribution of this paper to the literature is as follows. The paper first reviews the agronomic and policy options to contain MLN. We analyze the practicality of maize-free windows under the unique circumstances of tropical smallholder socio-economic environments where maize is the main food and cash crop and can be grown in overlapping seasons, including throughout the year as is the case in Kenya's sub-humid mid-altitude areas. We use multi-decade crop simulation models to generate yield data from maize-bean rotation sequences and compare the discounted net benefit streams from these crop sequences to determine their (financial) feasibility. Second, we compare this with the impacts that emerging and prospective MLN-tolerant hybrids would offer. We use an economic surplus model to assess the impacts of prospective MLN-tolerant hybrids compared to the current varieties. The results from the crop simulation and economic surplus models are used to make assessments on what strategy offers the most realistic MLN control approach given the circumstances of smallholder production in Kenya and Ethiopia.

In the next section of this paper we first provide a brief review of the MLN control options as currently understood in the literature and in policy discussions. The third section then presents the models and methods used. The fourth section presents the results comparing genetic tolerance with maize rotations, before concluding in the last section.

2. MLN control strategies: a review of agronomic, genetic and policy options

2.1. The role of best agronomic practices

Crop rotations and maize-free windows are short-term measures deemed to be particularly effective in containing MLN. Farmers would thereby desist from growing maize for at least one season, by rotating maize with a non-grass crop such as a legume. This approach only works to contain MLN outbreaks if many farmers can skip maize over large and contiguous maize growing areas during a season. Yet, what are the prospects of widespread crop diversification (or even periodic divestiture from maize) in the prevailing maize dominated systems? Economic realities may contradict this crucial recommendation and may call for complementary actions to make widespread maize-free windows feasible and implementable.

Additional MLN containment measures require farmers to apply routine best agronomic practices to help minimize the effects of the disease, including timely planting and weeding, correct plant spacing and adequate fertilizer application for maximum plant health. Since seed can be one of the transmission mechanisms, the use of clean and certified seed (as opposed to recycled seed) is critical. Chemical spraying at early establishment can reportedly mitigate MLN spread (Nelson et al., 2011). Additionally, it is recommended that crop debris should not be moved around, these being potential inocula (Samson et al., 2014).

Diversification and rotations are well established and widely recommended farm practices in their own right. However, in eastern Africa's maize-based systems, these are seldom consistently practiced: e.g. only 13% of maize farmers practiced such crop rotations in response to MLN in Kenya (Prasanna, 2015). An important reason involves the economic imperatives of continuous maize growing compared to implementing sound crop rotations. If continuous maize monocropping (CMM) is more economically attractive than maize rotations, then rotations and maize-free windows, although agronomically sensible, become economically uncompetitive and likely unacceptable to farmers. A similar phenomenon has been observed where poor farmers typically mine soil nutrients because doing so is economically optimal given the prevailing economic realities, including lack of liquidity, high input and low crop prices (Marenya and Barrett, 2009) and thereby undermine the long-term sustainability of their farms (Reardon et al., 1999).

2.2. The role of maize breeding: Towards MLN tolerance and resistance

The use of MLN tolerant or resistant varieties is arguably the most enduring means of managing MLN (Prasanna, 2015).[1] Superior resistance to MCMV is widely available in tropical maize seed stocks and provides the best control for the disease (Nelson et al., 2011). Ultimately, resistant varieties need to be developed for all agro-ecological zones because most maize producing areas have been affected or are vulnerable. One of the policy recommendations is to make MLN tolerance in maize one of the important criteria for varietal release by the National Variety Release Committees (NVRCs). The NVRCs can then prioritize the expedited release of high-yielding, MLN-tolerant (resistant) maize varieties. Similarly, national and international programs should intensify efforts to introgress MLN tolerance in the commercial genetic pools in all countries including those that are not yet affected by MLN (Prasana et al. 2015).

The success of this recommendation will largely depend on the effectiveness of the region's seed systems (including research, regulatory and seed companies both private and public). MLN tolerant germplasm can be made freely available for introgression by international and national breeding programs as public goods. This model will ensure a level playing field in accessing MLN tolerant germplasm hence avoiding the threat of only a few companies dominating the market with tolerant varieties.

2.3. The role of phytosanitary institutions

National plant protection organizations (NPPOs) have a crucial responsibility in ensuring that, without MLN-free seed certification, there is no movement of commercial seed from MLN-endemic to non-endemic countries. These measures should be in force until all NPPOs in the region can confirm that seed companies with production facilities in the MLN-endemic countries are able to produce 100% MCMV-free commercial seed. The requirement that all seed has the necessary MLN-free certification from the NPPOs may in the short run constrain regional seed trade, but the benefits of these rules (in curbing the spread of MLN) would far outweigh the real risks associated with introducing MLN in non-endemic maize-producing zones (Prasana et al. 2015).

To support MLN research and other maize improvement programs, exchange of research materials across borders should not be interrupted. The exchange of small lots of thoroughly tested seed of important breeding materials, including MLN-tolerant parental lines, will require the establishment of MLN quarantine sites (far removed from major maize producing areas and monitored by qualified pathologists) in each of the major maize-growing countries in sub-Saharan Africa (Mezzalama et al., 2015). One way to do this would be to develop regional networks of certified, accredited laboratories mandated to undertake standardized testing of MLN-causing viruses, especially MCMV, in seed production fields and in research as well as commercial seed lots. Certificates issued by NPPOs must clearly indicate the tests done

[1] This section and the next draw heavily from Prasana et al. (2015).