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Maize Lethal Necrosis a Viral Disease, an Emerging Treat to Maize Production in Ethiopia: A Review

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Abstract

In Ethiopia the majority of small holder farmers are practicing subsistence farming on less than a hectare of land. But the largest component of the farmers is growing and producing of maize on the subsistence farm. It accounts 55.6% yield production among cereals. But currently newly emerging viral diseases is limiting its production in Ethiopia since introduced in the year 2013/2014 cropping season in the Upper Awash Valley areas. This disease was latter recognized as Maize Lethal Necrosis Disease (MLND) to cause various levels of damage ranging from low infection rate to total crop failure. The exact time of MLND occurrence in Ethiopia is not determined but its presence was confirmed in 2014. Subsequent assessments and reports indicated that the disease is widely distributed in major maize producing areas of Ethiopia; namely, Amhara, Benishangul-Gumuz (BSG), Oromia, Southern Nation, Nationality and Peoples (SNNP) and Tigray regions. It seriously affected yields and the infected plants regularly remain barren, small or deformed ears and no seed at all. Vectors and infected soil and seed are responsible agents for the spread of MLND. Since MLN is strange for the country there is no integrated management strategies developed for the management of MLN. However, some of the management options available from world experience showed that significant loss of the crop can be reduced using management options integrally. As the maize genotypes reaction is base for breeders, Ethiopian and some Kenya maize germ plasmas against the disease are on trial in Ethiopia. Capacity building of scientists and regulatory agencies should be emphasized to diagnose MLND causing viruses and formation of new hybrids and breeding populations from resistant sources should be future prospect.

Keywords: ELISA, Distribution, Incidence, LFA, Maize Lethal Necrosis, RT-PCR, Ethiopia

Introduction

Maize is a staple food for over 70 million peoples in Africa, and predominantly produced and consumed directly by small scale holder families. Cereals in Ethiopia accounted for about 79.88% and 86.08% of the total grain cultivated areaandproduction respectively. Among cereal crops, maize is Ethiopia's leading crop both in terms of production and cropland coverage with 5.6% yield produced and 47.84% of total cultivated land in 2016 by 8,581,941 farmers (CSA, 2016). In terms of cultivated area, it is the first most widely cultivated crop in Ethiopia. Ethiopian farmers grow maize, primarily for subsistence with 75% of all maize output consumed by farming households, making it a key crop for overall food security and for economic development in the country (CSA, 2016).

However, maize production is threatened with various weeds, insects, and diseases caused by fungi, bacteria, viruses and nematodes were among usual problems to the maize growing parts of Ethiopia. Among insects, maize stack borer and American fall army worm are the most challenge in maize production. Maize grey leaf spot, maize streak virus, maize rough dwarf virus, common stum, Tricicum leaf blight on some maize varieties, rusts were among pathogens challenging maize production in parts of Ethiopia in which maize is growing. Besides, currently virus like symptoms later recognized as maize lethal necrosis disease has reported to cause several levels of damage on the crop. This newly emerged disease threatens its production since introduced to Ethiopia [1-8].

The occurrence of virus like symptoms (chlorotic mottle on maize leaves, mild to severe mottling and necrosis) were reported in Kenya after causing significant maize damage in farmers' fields [1-4]. Latter the disease was diagnosed as Maize Lethal Necrotic Disease (MLND) or Corn lethal Necrosis Disease (CLND) [9-12]. In Ethiopia, the disease was first observed and reported in 2013/2014 cropping seasons to cause various levels of damage ranging from low infection rate to total crop failure [13-16]. Maize growing areas in Ethiopia has previously assessed for the prevalence of the disease and its conformation has done at Ambo Plant Protection Research Center and trampled via ELISA test. This review discusses on MLND of what has been done so far and highlights of future research interests in Ethiopia.

History and Distribution of Maize Lethal Necrosis Diseases (MLND)

The Maize Lethal Necrosis Disease (MLND) is synergistic co-infection of maize as a result of two viruses such as Maize Chlorotic Mottle Virus (MCMV) and any several viruses in the Potyviridae group, like the Sugarcane Mosaic Virus (SCMV), Wheat Streak Mosaic Virus (WSMV) or Maize Dwarf Mosaic Virus (MDMV). The double infection of the two viruses gives rise to what is called MLND, also referred to as Corn Lethal Necrosis (CLN). It was first identified in USA in 1976 where it was reported to be caused by double infection [17-22]. It is a new disease for Africa and a serious new emerging disease has occurred in Eastern Parts of Africa. This first outbreak of maize lethal necrotic disease was first reported in East Africa in September 2011 along rift valley regions of Kenya [23]. In Kenya a lot of Provinces to have the occurrence of the disease were reported currently and subsequently in Rwanda [1] and the Democratic Republic of Congo

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[17]. In August 2012, this disease was also reported in Tanzania around border regions especially Northern and along Lake Zone [20-24]. In Uganda, the disease was first reported in October 2012 in Busia then in border district of Tororo, Mbale and Kapchorwa [25-27]. MLND was first reported in February 2013 in Northern Province of Rwanda and it then spread to western Province [1,25]. And it is a recent introduction and arrival to Ethiopia in 2013/2014 cropping season in the Upper Awash Valley areas [26-38]

Losses and Impact of MLND in Ethiopia

MLND is a big challenge to maize production in East Africa countries including Ethiopia. Losses as a result of the disease depend up on different factors like plant stage infection, type of variety, type of virus strain and environmental conditions [10-14]. Yield loss ranging 31-70% have been recorded in Eastern Uganda [14]. High losses of yield between 50-90% have been recorded in north central Kansas and South central Nebraska in maize crop both in artificial and natural inoculation [10].

Even if its arrival in Ethiopia is intraclast, it threatens and limits the production of maize to its optimum. Subsequent reports on the significant loss of maize yield as a result of the disease was received since its introduction to parts of Ethiopia where maize is growing. Since its notation in Upper Awash Valley areas of Ethiopia, it has caused total crop failure in the main cropping season of 2014 [18]. The susceptibility of the crop for the disease is not limited to one growth stage but all. All stages of development starting from seedling up to near maturity are unmasked [5-8]. As the seedling stage is the most vulnerable for infection it can cause total crop loss [18-20].

The loss is due to infected maize plants with small ears, distorted and set little or no grains. On the other hand the costs to produce maize are increasing as a result of farmer's usage of herbicides and insecticides to control weeds and vector transmitters. Any disruption of production invariably weakens food and nutrition security for a large section of the population. In Ethiopia, the adverse impact of MLND is already apparent at farm, county and national levels. At the farm level, affected famers have experienced total crop loss. Besides the costs incurred by seed suppliers for seed treatment of maize is another unlooked dissipation. Therefore, proper remedy should be put to manage and reduce losses caused by the disease and optimize the production [21].

Distributional Status of MLND in Ethiopia

The spread of Maize Lethal Necrosis (MLN) in the maize growing regions of Ethiopia has intensified since the first outbreak was reported in Upper Awash valley of Ethiopia in June 2014. Subsequent assessments were conducted in major maize growing regions of Ethiopia; namely, Amhara, Benishangul-Gumuz (BSG), Oromia, Southern Nation, Nationality and Peoples (SNNP) and Tigray regions. The assessments were carried out during the main and off-seasons of 2014-2016. Data collection on disease incidence and severity was based on symptom observation in the susceptible control.

As soon as the disease was observed three preliminary assessments were done from July 24-Sep 2 of 2014 in collaboration with EIAR-CR Directorate Office and CIMMYT, CIMMYT-Eth and Kenya and technical committees of MoA. They developed protocol for identification of MLND in Ethiopia. Field assessment of MLND was done on both grain and seed production farms of four administrative regions of Ethiopia, namely: Amhara, Benishangul-Gumuz (BSG), Oromia and Southern Nation, Nationality and Peoples (SNNP). In 2015 off season, another field survey was done with the aid of ASARECA in five administrative regions including Tigray besides the above four regions. Symptomatically the diseases incidence was evaluated between the range of 0 and 100%. Tigray (Mehoni, Alemaxa) (60-100%), Oromia (East and West Wellega zones, CRV, Ilubabor) (10-60%), Amhara (Ethio Agri seft, Ayehu farm) (70-100%), SNNPR (Arbaminch) (10-20%) and Benishangul-Gumuz (Kamashi zone) (0%) (Girma Demissie).

Mengistu reported that the incidence of MLND in Oromia and Benishangul-Gumuz that ranges 10-100% and 30-100% respectively [22]. Also this author reported the incidence of this disease as 10% in Southern Nation, Nationality and Peoples (SNNP). Similarly Bekele et al. [4] reported the incidence of this disease in different parts of Ethiopia as 10-60% in Amhara, 40-100% in Benishangul-Gumuz, 3-60% in Oromia and 80-100% in Southern Nation, Nationality and Peoples (SNNP) in 2014 main cropping season. In 2015 main cropping season [4], reported the incidence of MLND in SNNP and Oromia which lie in the ranges of 5-100% and 0-85% respectively. Higher level of MCMV distribution was observed in Tigray region during the main and off seasons as compared to Amhara region. As revealed by the survey result conducted the incidence of the disease was at different rate ranging from low incidence (3%) to high incidence (100%) infection rate.

As a result of the test conducted SCMV and other potyviruses in combination with MCMV causes MLN are already prevalent in different agro-ecologies of the country including in maize producing areas. Wider distribution of MLN disease in Ethiopia was more evident from the fact that MCMV was frequently detected in most leaf and grain samples obtained from different areas surveyed. This indicates that the greater distribution of the disease across the country is seeking implementation of appropriate control measures. The highest significant cause as a result of the disease was observed during the off season than the main growing season. The probable reason may be maize grown under irrigation could be the only green vegetation in the area that attracts massive insect vectors and the dry and hotter conditions during the off-season could be a conducive environment for reproduction and movement of the insect vectors to fast spread MLN causing viruses [4].

Transmission and Spread of MLND

As with many viruses, a carrier is required for spreading the virus from plant to plant and field to field. The absence of the molecular machinery made plant viruses not to replicate themselves. As a result, they need to move from infected to uninfected plant for survival otherwise, they may not be able to survive. The robust nature of plant cell wall made viruses not to penetrate and enter to inside to cause damage. Viruses need wounds created by some other forces to get entered [39-41].

In Ethiopia no one has reported regarding to the transmission of MLND. Currently there is no research in progress on potential alternate host and responsible vectors of spreading MLND as it enables us to determine the extent of a potential inoculum reservoir for the different viruses involved. Although reports are available elsewhere in the world, several insects and others were found associated with the diseased maize plants in the field of Ethiopia. But insects are not tested for their ability to efficiently transmit SCMV and MCMV in Ethiopia. From the world experience, MCMV is transmitted by vectors mainly beetles [12] rootworms thrips [13] and stem borers. SCMV is transmitted by several species of aphids in non-persistent manner [41]. WSMV is transmitted by mites in persistent manner [16,40]. MCMV is transmitted by aphids in non-persistent manner [32]. Additionally, infected soil [25] and seeds have been reported as a reservoir and a means of viruses transmission [12-15]. Human activities such as using materials in infected field without closely washing can transmit the disease causing viruses from infected to uninfected fields. The virus may also be spread through soil and through infected plant debris since the virus can survive in plant residues [26]. Maize production in Continuous manner in the same field greatly increases the incidence of the viruses and vectors.

Life Cycle of the Pathogens

Available information's across the world indicated that the pathogens causing MLND can survive between cropping seasons. They can survive in infected maize residuals and contaminate soil, alternative hosts like sorghum, [35-37] millet, [3,37], Johnson grasses [37] and other grasses in the family Poaceae [31] can also harbor MLND viruses and act as source of inoculums in the next seasons of maize production.

In Ethiopia several suspected alternate host plants including Johnson grass, unidentified grass species, Digitaria sp., sedge grass, Setaria sp. and sugarcane were found in which the presence of MLND was detected. This suggests that grass families are the most alternate hosts to carry MLND causing viruses [4].

Diagnosis of MLND

Proper identification of the causative agent causing the suspected disease is the major aim of controlling diseases [1,39] Several methods have been involved for the identification of plant viral diseases. These methods include; serological methods, nucleic acids based methods (Singh and Singh; Naidu et al.; Webster et al.; Punja et al.; Trigiano et al.), electron microscopy [41], physical properties of a virus (that is, thermal inactivation point, dilution endpoint, and longevity *in vivo*) [36], transmission tests, and symptomatology [34-37]. Plants affected by MLND shows symptoms like stunting, necrosis, mottling, streak and mosaic pattern, elongated yellow streaks parallel to leaf veins, streaks may coalesce to create chlorotic mottling. Chlorotic mottling may be followed by leaf necrosis [25,30] which may lead to "dead heart" symptom and plant death [38], premature aging of the plants [10], failure to tassel and sterility in male plants, malformed or no ears [10,24,37], failure of cobs to put on grains and rotting of cobs [38].

Even though symptomatology is one key of disease identification, as a result of different circumstances like varying in genotype, time of infection, environmental conditions and the potential for multiple infections, visual observation judgments should be assured through serological assays such as ELISA and/or molecular tests such as RT-PCR [18,22,38].

In Ethiopia, various detection methods of virus have been applied including visual symptomatology, use of indicator plants, serological methods and molecular techniques. For DAS-ELISA and LFA test the collected samples from major maize producing areas were exposed to serological analysis of MCMV and SCMV in the leaf tissue and seeds of maize, sorghum and popcorn. In the case of Reverse transcription-polymerase chain reaction (RTPCR), after extraction of total RNA from Maize seeds and fresh young leaf tissues, amplification of MCMV and SCMV viruses from suspected maize leaf and seed samples was done with various derivatives of RT-PCR, viz. RT-PCR using porous ceramic cube, multiplex RT-PCR and normal RT-PCR (Figures 1-4).

Confirmation of MLND in Ethiopia

Even if a lot of researches are needed to conduct, the presence of

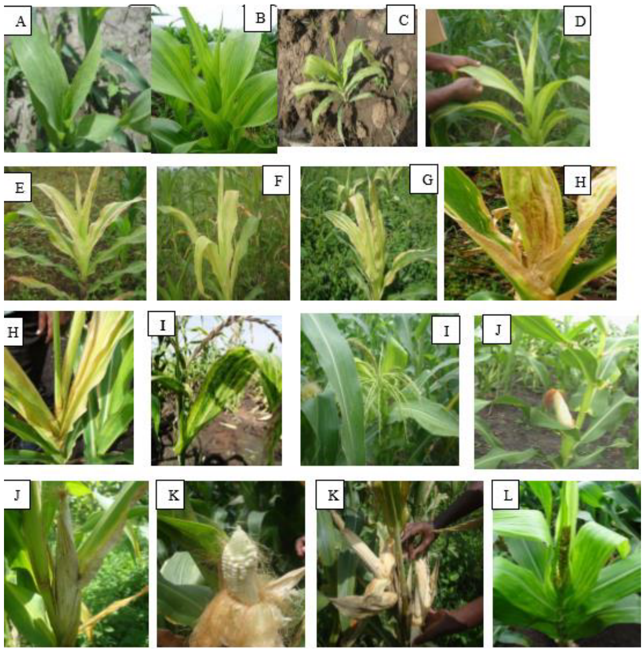

Figure 1: Commonly observed MLN disease symptoms under field conditions in Ethiopia. The leaf symptoms above represent, typical chlorosis (A), mosaic (B), mild mosaic at seedling stage (C), severe chlorosis (D), leaf necrosis starting from margins (E).

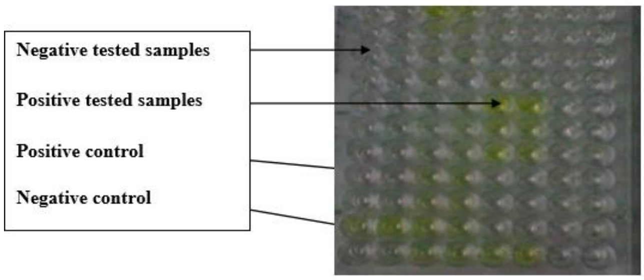

Figure 2: DAS-ELISA results for tested samples: DAS-ELISA showing positive (yellowish) and negative (colorless) tested samples, and positive and negative controls [4].

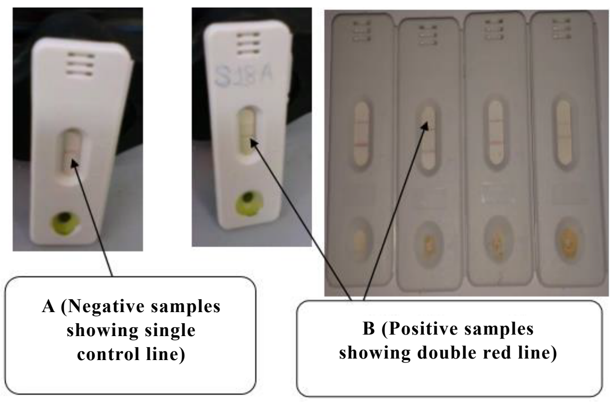

Figure 3: Lateral flow assay results for tested samples: showing MLN negative (A) and positive (B) [4].

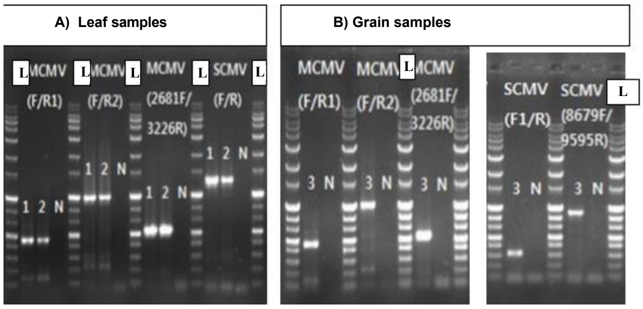

Figure 4: Detection of MLND using Multiplex RT-PCR, and RT-PCR using porous ceramic cube: testing of maize leaf (A) and seed (B) samples from Ethiopia substantiate the presence of MLN. For respective pairs of primers, numbers 1, 2 and 3 indicate test samples. N=healthy maize plant used as negative control. L=DNA size marker (100bp) [4].

the disease has got its conformation in laboratory since its presence has observed. The collected samples showed the presence and the variable domination of pathogens across the country. From the result reported during, MCMV was the most prevalent that was detected in more than half of the samples either alone or in combination with SCMV, whereas SCMV was detected in less than half of the samples. The proportion of samples with MCMV alone was 39% compared to 13% for SCMV only. The combination of both MCMV and SCMV were detected in 25% of the samples. MCMV was also detected in 65% of non-maize (alternate host) samples either alone or in combination with SCMV, whereas SCMV was detected in 19% of the samples. The samples that were found to harbor MCMV alone were 50%, whereas only 4% of the samples were found to carry SCMV alone. Several suspected alternate host plants including Johnson grass, unidentified grass species, Digitaria sp., sedge grass, Setaria sp. and sugarcane were found in which the presence of MLND was detected. Whereas SCMV was detected only in Johnson grass and Setaria sp. This suggests that grass families are the most alternate hosts to carry MLND causing viruses [4]. No available information is present that reasons out why MCMV is most prevalent than SCMV on the experiment.

Another report by Mengistu 2016 showed that MCMV is less diversified than SCMV in in Benishangul-Gumuz and Oromia Regions of Ethiopia and he confirmed that the result was in agreement with other studies. As a result of similarity shared by MCMV isolates and individual haplotypes, the genetic evolutionary network based on the number of mutational events drawn showed less number of haplotypes. This indicates that SCMV is more diversified than MCMV in the study areas. The samples collected from Assossa area showed weak reaction for the test of SCMV and this might be due to difference between this virus and the SCMV from other area. Although some weak reaction and mostly no reaction involved with the MCMV for tested samples of Assossa was assured. This might be as a result of the presence of unusual or variant isolates, thereby, limiting the use of serological tests for sensitive and specific identification of these viruses in maize [1]. Also may be due to the polyclonal nature of the antibodies.

Another report by Tesfu reported that there was higher MCMV viral titer in SCMV-MCMV co-infected maize plants compared with that in MCMV infected maize plants. She reasoned out the domination of MCMV over SCMV-MCMV co-infection was as a result of the presence of SCMV HC-Pro protein. Similarly Syller [34] who reported that HC-Pro, the silencing suppressor encoded by Potyviruses, could enhance the pathogenicity and accumulation of other heterologous viruses.

Phylogenetic Tree Analysis of Ethiopian MLND Isolates

Samples contained with MCMV and SCMV were exposed for Phylogenetic tree analysis based on the complete genomes of MCMV. The result confirmed that the isolates of Ethiopia found were highly similar (>99% identity) with those found previously in East Africa [1]. In contrary, phylogenetic tree constructed using coat proteins of the sequenced SCMV isolates from Ethiopia were found to be similar to each other and to those found in Rwanda [1] with 96% identity, but relatively distant from those originally found in Kenya [1]. Considering the nucleotide sequence, the Ethiopian samples showed the highest similarities, 97-99% for MCMV and 95-98% for SCMV, with the Ethiopian accessions having maize as host and with other isolates from Kenya, Rwanda, USA, China, Iran and Argentina [22].

Maize Lethal Necrosis Disease Management

The goal of plant disease management is to reduce to its minimum level that will not cause significant loss and damage the crop (Maloy, 2005). Proper disease management is achieved through the integrated use of different options. Controlling MLND is difficult because of two reasons. First one is the disease is caused by combination of two or more viruses which are difficult to differentiate each based on visual symptoms and second is the vectors causing the viruses can be carried by wind for long distances. Reduction of initial inoculums through Pathogen exclusion and eradication, reducing the rate of infection via avoidance, plant protection and resistant or tolerant varieties are the most and widely used methods of controlling MLND in which the world is experiencing.

In Ethiopia a little research conducted on eight maize genotypes such as Melkassa 1, Melkassa 2, Melkassa 4, MH 140, MH 130, MHQ 138, JIBAT and CML 445 showed the presence varied reactions against MLND (Kalkidan Tesfu, 2017). She inoculated the viruses both as individual and combination at greenhouse of National Agricultural Biotechnology Research Center (NABRC). Varied levels of severity among all genotypes were recorded. However, among the genotypes used in the study, Melkassa 1, 2 and MHQ 138 were found to be relatively resistant than the other genotypes. Her result was in line with Jacob, (2015) in Tanzania who reported that landrace genotypes were better adapted against MLND than either improved varieties or inbred lines.

The phylogenetic relationship of Ethiopian isolates with other countries could be a base to put management practices applied in to hand of Ethiopia condition. So that relevant recommendations regarding to MLND management in Ethiopia could be monitoring the field once a week at all stages of development for symptoms development, uprooting diseased plants and burn them immediately to stop the spread of the disease, controlling the vectors through pesticides by spraying with diazinon 60% EC (1-1.5 lit/ha), malathion 50% EC (2 lit/ha) and lambda-cyhalothrin 5% (0.2-0.4 lit/ha) insecticides. Also rotation with pulse crops use disease-free seed and plant with the recommended rate of fertilizer, weed fields regularly to eliminate alternative hosts of the insect vectors and not planting a new maize crop near infected fields [11].

Crop rotations and maize-free windows are short-term measures believed to be particularly effective in containing MLN. Farmers should have to desist growing maize for a season and legume crops should be grown instead. Farmers are needed to apply different agronomic practices 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 is critical. Chemical spraying at early establishment can reportedly mitigate MLN spread [25]. Additionally, it is recommended that crop debris should not be moved around, these being potential inocula [30].

The use of MLN tolerant or resistant varieties is the soundest method of managing MLN [23]. High performance resistor to MCMV is widely available in tropical maize seed stocks and provides the best control for the disease [25]. Lastly resistant varieties should have to be developed against MLND for all agro ecological zones of maize producing areas. 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). MLND resistant maize genotype release should be intensified by national and international programs to limit its damage in all countries including those that are not yet affected by MLN [27].

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 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 [23].

Progress Research on Maize Genotypes against MLND in Ethiopia

Understanding how different maize genotypes react to the different virus is a key in selecting for the purpose of breeding. One of the most important things in crop improvement center is germplasm diversity. Because improving has a paramount importance in achieving the goal of having resistance varieties for specific diseases causing organisms. Searching for resistance and or tolerance of maize genotypes for MLND is important to produce the crop to its optimum. In maize producing of the world areas maize genotypes have been inoculated with the disease as alone or in combination. They got significand result on reducing losses as a result of the disease.

Existence of genetic resistance to MLND causal agents, the MCMV and SCMV has been confirmed [39]. Research outputs in eastern part of Africa prevailed that maize genotypes reaction against pests and diseases including MLND has got attention and prevailed that the hybrids showed higher performance over landraces in both yield and resistance [29]. In Ethiopia there is no research output reported on maize genotypes against MLND. But currently Ambo Plant Protection Research Center is trying to screen the maize genotypes against the disease. The genotypes on screening are Ethiopian and some Kenyan genotypes are also trying for their reaction.

Conclusion

Maize lethal necrosis disease (MLN) is a new reported virulent maize disease in eastern Africa, first confirmed in Kenya in 2010 and subsequently spreading to neighboring countries. It is the result of the co-infection of two or more viruses. In Ethiopia, the disease was first observed and reported in 2013/2014 cropping seasons to cause various levels of damage ranging from low infection rate to total crop failure. The rapid spread of MLN in parts of Ethiopia and the potentially enormous threat to food security and trade has aroused the interest of governments, national and global research organizations, and the private sector, culminating in several initiatives and its distribution in Ethiopia was reported in different major maize producing areas. Now the disease is devastating the crop as a result of different reasons to control. From these differentiating the symptoms of each virus due to combination effect and carrying of vectors with wind for long distance made MLND not to manage.

The disease also recorded in both main and off-season irrigated maize fields and all available local and commercial maize varieties were affected by the disease. Vectors like thrips, aphids, beetles, rootworms are responsible for spreading the virus from plant to plant and field to field. Infected soil and seed are also mechanisms of transmission for the disease. Mono-cropping of maize is also the one which can increase the incidence of the viruses and vectors too. Research conducted somewhere else in the world continues to show that crop rotation greatly reduces the incidence of (MCMV) in first year corn even in susceptible hybrids. No resistant hybrids have been developed to date but tolerable hybrids have been reported.

For the rapid identification of the causative agent causing the suspected disease, there are different diagnosis tools. So using symptoms, serological tests, nucleic acid based methods, polymerase chain reaction and sequencing of nucleotides we can assure the presence of the virus on the host. Progressive research on screening and identification of maize genotypes against MLND is on trial in Ethiopia. Managing the virus using integrated disease management principle is appropriate and the use of MLN tolerant or resistant varieties is the soundest method of managing MLN.

Recommendation and Future Research Prospects

Relevant recommendations regarding to MLND management in Ethiopia should be applying all the options integrally. Small holder farmers should have to use routine agronomic practices to help minimize the effects of the disease. Since seed can be one of the transmission mechanisms, the use of clean and certified seed is critical. Farmers would have to rotate maize with a non-grass crop such as legumes. Farmers should have to use Melkassa 1, Melkassa 2 and MHQ 138 than the other maize genotypes. In order to manage MLND effectively in Ethiopia, the following questions needs to be answered: How do the virus strains causing MLND present in regions of Ethiopia differ in the rate of infection? What insect vectors are responsible for transmission of MLND causing viruses in Ethiopia? What is the relationship between MLND causing viruses and their insect vectors? How can these insect vectors be managed? How much seeds can contribute to transmission of the viruses causing MLND? What genes are responsible for host resistance? How can these genes be incorporated into seed stocks by breeders? What is the contribution of climate change to the spread of MLND? What makes MCMV dominant over SCMV and vice versa? And all the prevailing maize germplasms of Ethiopia should be tested for their reaction to MLND as this might be the basis for breeders. As MLND gives rise to secondary fungal infections in the ears or grains, it should not be eaten by humans or animals. The plants should be removed immediately from the fields and infected ears and grains should be burnt.

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