African Journal of Rural Development, Vol. 2 (2): April - June 2017: pp.247-261 ISSN 2415-2838

Farmer knowledge, perceptions and management of maize lethal necrosis disease in selected agro-ecological zones of Uganda

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ABSTRACT

A new disease on the African continent called maize lethal necrosis disease (MLND) that has been reported to cause up to 100% losses in neighbouring Kenya, has since spread to Uganda. Production of maize in Uganda is now under threat from this devastating virus disease. Understanding farmers' knowledge, perceptions and management practices is a prerequisite to establishing an effective disease management approach to halt its spread in Uganda. A survey of 396 farmers from 14 major maize growing districts in five agro-ecological zones of Uganda was conducted in 2015 aimed at assessing farmers' current knowledge of maize lethal necrosis disease and practices for its management. Most farmers (58.1%) had not heard or observed MLN in their fields. The study reveals that 56.6% of the farmers interviewed first experienced MLN in the year 2014. There was uncertainty of the cause of MLN symptoms among 56.6% of the farmers. Most farmers observed MLN symptoms at one month after planting. Only 21.7% correctly identified MLN symptoms observed. The main MLN symptom observed by most farmers (60.6%) was chlorotic mottle on leaves. Up to 55.3% of farmers attempted to control MLN with the majority (77.4%) managing it through uprooting and burning the diseased plants, which they indicated was effective in managing MLN. These results suggest that MLN control could be achieved by enhancing farmers' knowledge and considering successful farmer MLN management practices when developing and promoting management practices for this disease.

Key words: Farmers' knowledge, maize lethal necrosis, Uganda

RÉSUMÉ

Une nouvelle pathologie sur le continent africain appelée la pathologie de la nécrose létale chez le maïs a été rapportée comme cause de jusqu'à 100% de pertes au Kenya, et s'est depuis propagée en Ouganda. La production de maïs en Ouganda est donc maintenant menacée par cette pathologie virale dévastatrice. La compréhension des connaissances, perceptions et pratiques de gestion des agriculteurs est une condition préalable pour établir une approche efficace de gestion de la pathologie afin d'éradiquer sa propagation. Une enquête a été menée en 2015 auprès de 396 agriculteurs de 14 districts producteurs de maïs dans cinq zones agro-écologiques de l'Ouganda, afin d'évaluer les connaissances actuelles des agriculteurs sur pathologie et les pratiques pour sa gestion. La plupart des agriculteurs (58,1%) n'avaient pas eu d'information sur la pathologie ni observé ses symptômes dans leurs champs. L'étude révèle que 56,6% des agriculteurs interviewés ont eu l'expérience de la pathologie pour la première fois en 2014. Il y avait une incertitude quant à la cause des symptômes chez 56,6% des agriculteurs. La plupart des agriculteurs ont observé les symptômes pathologiques un mois après le semis. Cependant, seulement 21,7% ont correctement identifié les symptômes. Le principal symptôme identifié par la plupart des agriculteurs (60,6%) était la marbrure chlorotique sur les feuilles. 55,3% des agriculteurs ont essayé de contrôler la pathologie, avec la majorité (77,4%) procédant par déracinement et combustion des plantes infectées, ce qui selon leur dire, était efficace. Ces résultats suggèrent que la pathologie pourrait être contrôlée en améliorant les connaissances des agriculteurs, et en considérant les pratiques de gestion réussies lors de l'élaboration et la promotion des pratiques de gestion de cette pathologie.

Mots clés: Connaissance des agriculteurs, nécrose létale chez maïs, Ouganda

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Received: 27 May, 2016
Accepted: 7 December, 2016
Published: 30 June 2017

INTRODUCTION

Maize (*Zea mays* L.), also called corn, is one of the most crucial and strategic cereal crops in Africa and the developing world in general (Bonavia, 2013). Maize is the most important cereal food crop in sub-Saharan Africa (SSA), particularly in eastern and southern Africa where it accounts for 53% of the total cereal area and 30-70% of total caloric consumption (Langyintuo *et al.,* 2010). In Uganda, the maize crop is cultivated by over 3.6 million households on about 1.1 million hectares of land (UBOS, 2015). Over the last decade (2004-2014), both maize area and production in Uganda increased dramatically. Harvested area increased from about 750,000 hectares in 2004 to 1,105,000 hectares in 2014 (FAOSTAT, 2015). Even though the area under maize production in Uganda has been increasing, farmer yields have remained stagnant at around 2.48t/ha in recent years (FAOSTAT, 2015) which is below the potential yield of 7.5 tons/ha which are achievable utilizing the current area under maize by utilizing improved varieties and crop management technology (AATF/NARO, 2010). The failure to attain potential yields is due to various abiotic constraints including drought, declining soil fertility, highly acidic soils, soil erosion, and high temperatures (Pingali, 2001) and biotic constraints including diseases like leaf blight, maize streak disease (MSD) and gray leaf spot (GLS) (Bigirwa *et al.,* 2001) and insect pests such as stem borers, leafhoppers, aphids, army worms, cutworms and grasshoppers, grain moths and weevils (Purseglove, 1998). However since 2013, the major threat to maize production in Uganda is the maize lethal necrosis disease (MLND) (Asea, 2013; IPPC, 2014).

Maize lethal necrosis disease is caused by the double infection of maize plants with Maize chlorotic mottle virus (MCMV) and any of the cereal viruses in the Potyviridae group, such as Sugarcane mosaic virus (SCMV), Maize dwarf mosaic virus (MDMV) or Wheat streak mosaic virus (WSMV) (Goldberg and Brakke, 1987; Scheets, 1998). The MLN affected maize plants show symptoms that include chlorotic mottle on leaves, mild to severe leaf mottling and necrosis developing from leaf margins to the mid-rib, necrosis of young leaves leading to a "dead heart" symptom, and plant death (Wangai *et al.,* 2015). Severely affected maize plants have small cobs with little or no grain set and plants frequently die before tasseling (Wangai *et al.,* 2015). MLN outbreaks cause variable yield losses but have been reported to be as high as 90% in the USA (Niblett and Claflin, 1978, Uyemoto *et al.*, 1980) and 30 -100 % in Kenya (Adams *et al.,* 2012; Wangai *et al.,* 2015).

The MLN causing viruses are spread through insect vectors of the different maize causing viruses namely cereal leaf beetle (Nault, 1978) and thrips (Cabanas, 2013) for MCMV and various aphid species for SCMV and MDMV (Ford *et al.,* 2004) and wheat curl mites (Seifers *et al.,* 2009) for WSMV. The MLN causing viruses can be perpetuated between cropping cycles by farmers planting maize seeds infected with MLN causing viruses (Mikel *et al.,* 1984; Jensen *et al.*, 1991; Jones *et al.,* 2005; Marie-Jeanne *et al.,* 2011). This implies that farmer practices have the potential to affect the spread of the MLN disease. Indeed Richard (1980) and Walker and Wortmann (1994) have reported that farmers' traditional knowledge is based on generations of experience and the first step towards achieving acceptable interventions and sustained agricultural development is through appreciating farmers' knowledge (Thrupp, 1989). Thresh (2003) also emphasized that detailed research and a clear understanding of farming practices is required before an integrated virus disease management program can be developed and promoted because virus spread within a crop is facilitated by some cropping practices and limited by others. However, there is scanty information on farmers' knowledge and perceptions of MLN in Uganda. This study therefore aimed at investigating the farmer knowledge and perception of the maize lethal necrosis disease with regard to disease identification and how they are managing the maize lethal necrosis disease.

MATERIALS AND METHODS

Target sites. The study was conducted in 2015 and covered 14 major maize growing districts from 5 of 11 agroecological zones (AEZ) of Uganda (NARO, 1999). In the Eastern AEZ Tororo district was covered. The Eastern Agroecological Zone has an annual average rainfall of 1197mm with temperature ranges from 15-32.5 ^{0}C. In the Lake Albert Crescent Agro-ecological Zone (LACZ) the districts of Hoima, Masindi, Kibaale and Kiryandongo were covered. The LACZ has an annual average rainfall of 1259mm with temperatures ranging from 17.5-32.5˚C. The study in the South Eastern Agro-ecological Zone (SEAZ) covered the districts of

Iganga and Bugiri with average annual rainfall ranging from 1215-1328mm and temperature ranging from 15 to 32.5˚C, while in the Eastern Highlands Agro-ecological Zone (EHAZ) the districts of Mbale, Bulambuli, Sironko, Kween and Kapchorwa were covered. This zone has average annual rainfall of more than 1400 mm and temperature ranging from 7.5 to 27.5 ˚C. In the Western Highlands Agro-ecological Zone (WHAZ) the districts of Kasese and Kabarole with average annual rainfall of 1270 mm and temperatures ranging from 15 to 30 ˚C were covered.

Selection of respondents. The survey used a three stage sampling design with the agroecological zones as the strata and the sub-locations as districts and sub-counties which are administrative units in Uganda. In each agro-ecological zone the districts and sub counties were purposively selected based on the intensity of maize production with the help of District Agriculture Production officers. Within each target sub-county, the respondents were randomly selected based on a sampling frame developed with the help of District Agriculture Production extension agents who had clear information about their region. The sampling size was calculated following the formula adapted from Krejcie *et al.* (1970) based on total census data of 2014 (UBOS, 2014). A total of 396 respondents across agroecological zones were interviewed.

Data collection. Data were collected using a semi structured questionnaire administered through face-to-face interviews with the respondents. The questionnaire was developed to capture farmers' knowledge of, and experience with MLN disease and to document how they were addressing the problem. The questionnaire was pretested before being used in the main survey. The questionnaire had the following sections: a) personal and household characteristics b) farming system, including maize varieties grown, acreage and yield, land allocation to maize production and maize production constraints, c) awareness of recent maize lethal necrosis problems and how they cope with the disease. The personal and household characteristics questions included name, address, age, education, family size, major sources of food and major sources of agricultural information. Farmers were shown clear colored photographs of maize at different stages of MLN severity to determine their ability to diagnose the MLN disease. These pictures were based on a presentation by Biswanath *et al.* (2013). After the definition was clear, participants were asked questions on whether they had observed MLND in their fields, the typical symptoms associated with the disease, year when the problem was first observed in their fields, and the cultivars of maize most affected by the disease. The questions on actions taken by the farmers about the disease included what MLND control measures the respondents were aware of, and MLND control measures applied on affected individual farms of the respondents.

Data analysis. Survey data were encoded and analyzed using Statistical Package for Social Scientists (SPSS) version 16.0 statistical software (SPSS, Inc. 2008). Descriptive statistics were used in data analysis. Data were summarized using cross tabulations. The percentage of farmers who gave similar responses for each question was calculated for each region and those who did not respond to certain questions were excluded from the percentage calculation. Correlations were used to determine the relationship between socio-economic and production factors and MLN awareness or experience in farmer fields in the five agro-ecological zones regions surveyed.

RESULTS AND DISCUSSION

Socio-demographic profile of farmers interviewed. Gender analysis indicates that the majority of the respondents across the five agro-ecological zones were males (68.4%) as shown in Table 1. This is probably due to the fact that rural women are engaged in domestic activities which may limit their mobility and crucial opportunities for interaction with other stakeholders. It is common in sub-Saharan Africa that women are predominantly involved in farming, even though men act as the household heads and are in most cases the respondents to surveys such as this. However according to the 2014 census report (UBOS, 2014), Uganda's total population stood at 34,856,813 people with 2.82% more women than men. Hence efforts geared towards promoting and disseminating new MLND management technologies should also target women for wider impact.

Mean age of the respondents ranged from lowest in Eastern highland agroecological zone at 45.2 to the highest in Western highlands agroecological zone at 47.7with a mean of 45.2 across all agroecological

zones (Table 1). Older farmers are more likely have a wider experience in farming and hence use this experience to discern the symptoms associated with the MLN disease on their farms.

Most (49.7%) of the respondents had some formal education up to primary level or seven years in school, followed by ordinary level or eleven years in school (27.3%), no formal education (15.2%) (Table 1). Some (3.3%) of the respondents had attained Advanced level or thirteen years in school, Diploma (2.8%), 1.5% had attained University level and the least number of respondents (0.3%) had attained certificate level. Educated farmers are believed to have higher ability to perceive, interpret and respond to new information about improved technologies than their peers with little or no education (Langyintuo and Mekuria, 2008; Tabi *et al.,* 2010). More educated farmers are thus more likely to access information and advice from extension workers, which influence their adoption and use of improved MLN tolerant varieties and agronomic practices.

Mean household size across districts was 7.7 members; this is higher than mean household size in Uganda of 4.7 persons (UBOS, 2014). This implies that most households have sufficient labor to implement most improved MLN management technologies. It is recognized that labour is the most important of all the resources used in agricultural sector especially in Africa (Enete *et al.,* 2005). On average, the South eastern agroecological zone had the biggest households with an average of 8.6 members, followed by eastern highlands agroecological zone with 7.7 members and the Eastern agroecological zone with the smallest mean household size of 6.9 members.

Awareness and trends of MLND incidence. Across all agroecological zones, most farmers (58.1%) had not experienced MLND in their maize fields (Fig. 2). The disease was regarded as serious in Eastern highlands and Eastern zones where 66.9% and 61.3% respondents respectively reportedly had ever experienced it in their farms. However, the Western highland agro-ecological zone had the least percentage (17.5%) of respondents that had experienced the MLN disease.

Table 1: Socio-demographic profile of farmers interviewed from five agroecological zones

Social profile	Eastern (n=31)	Lake Albert Crescent Zone (n=122)	South Eastern (n=59)	Eastern Highlands (n=121)	Western Highlands (n=63)	Overall (n=396)
Gender						
Male	74.2	73.8	62.7	61.2	74.6	68.4
Female	25.8	26.2	37.3	38.8	25.4	31.6
Education Level						
No Education	16.1	13.9	13.6	16.5	15.9	15.2
Primary (P1-P7)	38.7	54.1	28.8	57.9	50.8	49.7
O Level	38.7	22.1	44.1	20.7	28.6	27.3
A Level	3.2	4.1	8.5	1.7	0.0	3.3
Diploma	0.0	3.3	3.4	2.5	3.2	2.8
University	3.2	2.5	1.7	0.8	0.0	1.5
Certificate	0.0	0.0	0.0	0.0	1.6	0.3
Mean Age	45.3	44.7	47.4	45.2	47.7	45.2
Household size	6.9	7.3	8.6	7.7	7.4	7.7

Source : Survey data 2015

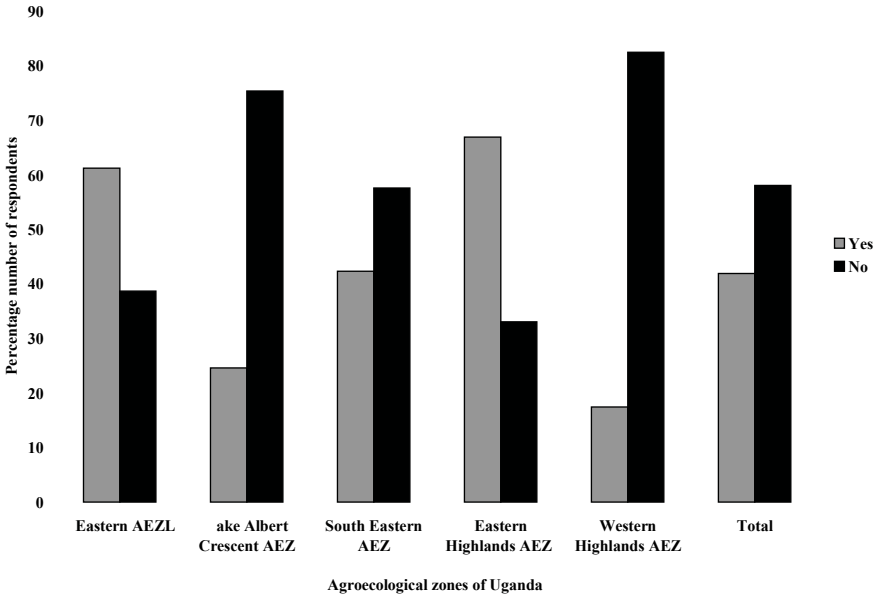

Figure 2: Percentage of respondents that have experienced maize lethal necrosis disease in different agroecological zones of Uganda

Table 2 presents results on when farmers first experienced MLND. The overall highest percentage (56.6%) of respondents first experienced MLND in 2014 followed by 28% in 2013, 8.4% in 2012 and 6.6% in 2011 (Table 2.0). The majority of respondents in the Lake Albert Crescent Zone (50%), South Eastern (86%), Eastern (47.4%) and Eastern Highland (58%) agroecological zones first saw MLND associated symptoms in 2014. However most farmers in the Western highland (54.5%) first saw MLND associated symptoms in 2011. The results in Table 2 suggest that MLND could have been in Uganda earlier than 2012 when it was first officially reported by Asea (2013).

Farmers' knowledge of perceived causes of the MLND Symptoms. Overall, the majority of farmers (56.6%) did not know the causes of the MLND associated symptoms seen (Table 3.0). However some 21.7% were able to correctly diagnose the MLND associated symptoms observed while 12.7 % thought they were due to poor soils. The Lake Albert Crescent agro-ecological zone had the most farmers (50.0%) who could correctly link the symptoms observed to the MLND disease while the South eastern had the least number of farmers who could correctly link the observed symptoms to MLND disease.

Most respondents reported that they saw symptoms associated with MLND when the maize was one month old (47.9%) (Table 3). This suggests the V6 growth stage of maize when it has six leaves is the most susceptible to the MLND disease according to most farmers. However, maize is susceptible to MLND at all growth stages from seedling to maturity (Manje *et al.,* 2015). It is probable that the other symptoms observed at later stages of growth may be confused with physiological maturity of maize. Other respondents reported (15.8%) seeing the MLND associated symptoms on maize three months after planting. In the Eastern agro-ecological zone most farmers reported seeing MLND associated symptoms on maize two weeks after planting. In the Lake Albert crescent zone, the South eastern and Eastern highland agroecological zone, most respondents reported seeing MLND associated symptoms on maize at one month old (Table 3).

Table 2: Years when farmers first experienced Maize Lethal Necrosis disease in their fields

Years	Agroecological zones					Total (n=166)
	Eastern (n=19)	Lake Albert Crescent Zone (n=30)	South Eastern (n=25)	Eastern Highlands (n=81)	Western Highlands (n=11)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
2011	10.5	6.7	0.0	1.2	54.5	6.6
2012	5.3	3.3	8.0	11.1	9.1	8.4
2013	36.8	40.0	8.0	29.6	18.2	28.3
2014	47.4	50.0	84.0	58.0	18.2	56.6

Table 3: Perceived causes of Maize Lethal Necrosis disease symptoms as reported by farmers

Perceived causes of The MLND symptoms	Agroecological zones					Total (n=166)
	Eastern (n=19)	Lake Albert Crescent Zone (n=30)	South Eastern (n=25)	Eastern Highlands (n=81)	Western Highlands (n=11)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
Bad soils	15.8	0.0	16.0	14.8	18.2	12.7
Lack of rain	0.0	6.7	0.0	3.7	0.0	3.0
Bad crop management	0.0	3.3	8.0	2.5	0.0	3.0
Maize Lethal Necrosis	36.8	50.0	8.0	9.9	36.4	21.7
Don't know	47.4	36.7	68.0	64.2	45.5	56.6
Water logging	0.0	0.0	0.0	2.5	0.0	1.2
Soil borne pest	0.0	3.3	0.0	1.2	0.0	1.2
Infected seed	0.0	0.0	0.0	1.2	0.0	0.6
Age of seeing MLND symptoms						
At One week after germination	10.5	3.4	12.0	8.6	0.0	7.9
At 2 weeks after germination	36.8	3.4	20.0	7.4	0.0	11.5
At 3 weeks after germination	21.1	10.3	16.0	8.6	27.3	12.7
At 1 month after germination	26.3	51.7	44.0	51.9	54.5	47.9
At 3 months after germination	5.3	13.8	8.0	22.2	9.1	15.8
At 2 months after germination	0.0	17.2	0.0	1.2	9.1	4.2

Farmers perception of predominant symptoms associated with Maize lethal necrosis and how it is spread. Most of the farmers (60.6%) reported that the main MLND associated symptom they experienced was a chlorotic mottle on leaves, followed by drying of leaves (24.8%) (Table 4). Based on the scoring scale developed by Biswanath *et al.* (2013), this suggests that the MLND symptoms seen by most farmers are at the stage when MLND severity is still low. A few farmers experienced the premature plant death (7.9%), premature drying of cobs (2.4%) and failure in tasseling (1.8%) phases of the MLND disease. The majority of farmers (27.9%) do not know how MLND is spread (Table 11). However many farmers (27.3 %) perceived it to be spread by insects while 23 % perceived it to be spread through planting materials. A few farmers (9%) perceived it to be spread by soil, 7.3% perceived it to be spread by wind, 2.4% perceived it to be spread by rain and 2.4 % perceived it to be spread by farm tools.

Susceptibility of maize varieties to maize lethal necrosis. Overall most respondents (40.1%) reported that maize lethal necrosis affected all the maize varieties they grew, 33% did not know and 25.5% did not perceive maize lethal necrosis as affecting all the maize varieties they grew (Table 5). This implies that sources of resistance from the local varieties need to be critically studied before being used in breeding studies to develop MLND tolerant/ resistant varieties. 42% of respondents from Eastern, 55.2% from the Lake Albert Crescent Zone and 40.5 % from the Eastern Highland reported that MLND affects all varieties they grow while 60.0% from South eastern and 60% from Western highland regions did not know whether MLND affected all maize varieties they grew (Table 5).

Table 4: Farmers perception of predominant symptoms associated with Maize lethal necrosis and how it is spread

Symptoms of maize lethal necrosis	Agroecological zones					Total (n=166)
	Eastern (n=19)	Lake Albert Crescent Zone (n=30)	South Eastern (n=25)	Eastern Highlands (n=81)	Western Highlands (n=11)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
A chlorotic mottle on leaves	57.9	37.9	76.0	67.9	36.4	60.6
Drying of leaves	36.8	44.8	8.0	22.2	9.1	24.8
Premature plant death	5.3	10.3	12.0	3.7	27.3	7.9
Failure to tassel/ sterility In male plants	0.0	3.4	4.0	1.2	0.0	1.8
Premature drying or rotting of cobs	0.0	3.4	0.0	2.5	9.1	2.4
All the above	0.0	0.0	0.0	2.5	0.0	1.2
Don't know	0.0	0.0	0.0	0.0	18.2	1.2
How necrosis is spread						
Planting materials	36.8	24.1	12.0	21.0	36.4	23.0
Insects	36.8	37.9	32.0	17.3	45.5	27.3
Wind	0.0	6.9	12.0	8.6	0.0	7.3
Rain	5.3	3.4		2.5	0.0	2.4
Soil	0.0	10.3	4.0	14.8	0.0	9.7
Farm tools	0.0	0.0	0.0	4.9	0.0	2.4
Don't know	21.1	17.2	40.0	30.9	18.2	27.9

Table 5: Susceptibility of maize varieties grown by farmers to Maize lethal necrosis disease

Does Necrosis Affect All Varieties?	Agroecological zones					Total (n=166)
	Eastern (n=19)	Lake Albert Crescent Zone (n=30)	South Eastern (n=25)	Eastern Highlands (n=81)	Western Highlands (n=11)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
Yes	42.1	55.2	32.0	40.5	10.0	40.1
No	31.6	34.5	8.0	27.8	30.0	26.5
Don't Know	26.3	10.3	60.0	31.6	60.0	33.3

Perceived yield loss due to MLND. Although a total of 166 respondents reported to have experienced MLND, 36.4% were not able to estimate the magnitude of yield loss attributed to maize lethal necrosis (Table 6.). However 37% reported that yield losses of less than 10% were attributed to MLND, 10.3% reported that above 11 to 21% yield loss was attributed to MLND, 4.2% of the respondents attributed 22-32% yield loss to MLND, 1.8% of the respondents attributed 33 to 43% yield loss to MLND, 6.1% of the total respondents attributed 44 to 54 % yield loss to MLND, 2.4 % of the respondents attributed 55 to 65% yield loss to MLND, 0.6% of the respondents attributed 66 to 76% yield loss to MLND and 1.2 % of the respondents attributed 77 to 87% to be due to MLND. At the time of this study, accurate yield losses to MLND in Uganda were completely missing from literature unlike in neighboring Kenya where a Community-survey based assessment of the geographic distribution and impact of maize lethal necrosis (MLN) disease in Kenya by Hugo De Groote *et al.* (2016) revealed yield losses of up to 59% due to MLND in western Kenya. Since this is still a relatively new disease to Uganda, farmers are yet to appreciate the potential magnitude of yield loss it can cause and hence the majority perceived relatively lower yield losses of 0 to 10% to be due to MLND which could infact be higher. Indeed a report by Kagoda *et al.* (2016) has now reported yield losses of above 50% in the most MLN affected districts of eastern Uganda which border Kenya confirming findings by Hugo De Groote *et al.* (2016). However methodological studies comparing the accuracy and cost of scientific observations with those from farmer perceived estimates, from individual observations would therefore be useful to provide a more accurate picture of the situation on the ground.

Farmers' perception of Season when high Maize Lethal Necrosis Disease Incidence is experienced. Overall the majority (54.0%) of the respondents reported that MLND is higher during the first season than the second season (Fig. 3). However most of the respondents represented by 61.1% in the Eastern, 44.4% in the South eastern and 52.5% in Eastern highlands reported that MLND was highest during the second season unlike in the Lake Albert Crescent and Western highland agro-ecological zones where most respondents reported that MLND was higher during the first season. This is in agreement with findings by Kagoda *et al.* (2016) who also reported that farmers in Tororo district in eastern Uganda reportedly experienced more MLN outbreaks during the second season. Environment plays a critical role in disease development thus the more disease in the first season or the second season depending on agroecological zones could be attributed to the longer rains and moisture experienced in either season. The long rains encourage farmers to plant maize late and this has been shown to increase the risk to MLN infection in neighbouring Kenya where planting late in the season (March) has the risk of having the MLN disease while early planting did not show any disease symptoms (Jumbo *et al.,* 2015). In addition to this, variability in maize seasons and phenology could significantly affect primary host availability, and consequently the incidence of the disease (Isabirye *et al.,* 2016). However other factors like vector population dynamics and agronomic practices, have been shown to be important in the disease cycle (Lafferty, 2009; zu Dohna and Pineda-Krch, 2010).

Management of MLND. Overall most respondents (55.3%) that experienced MLND attempted to control it (Table 7). Most of the respondents represented by 77.8% in the Eastern, 62.1% in the Lake Albert Crescent agroecological

Table 6: Perceived yield loss due to Maize Lethal Necrosis disease in the different agroecologies of Uganda

Perceived percentage yield loss to MLND	Agroecological zones					Total (n=166)
	Eastern (n=19)	Lake Albert Crescent Zone (n=30)	South Eastern (n=25)	Eastern Highlands (n=81)	Western Highlands (n=11)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
0 to 10%	36.8	72.4	36.0	25.9	27.3	37.0
11 to 21%	5.3	20.7	12.0	6.2	18.2	10.3
22 to 32 %	5.3	0.0	4.0	6.2	0.0	4.2
33 to 43%	5.3	0.0	0.0	2.5	0.0	1.8
44 to 54%	10.5	0.0	0.0	9.9	0.0	6.1
55 to 65%	5.3	0.0	4.0	2.5	0.0	2.4
66 to 76%	0.0	0.0	0.0	1.2	0.0	0.6
77 to 87%	5.3	0.0	0.0	1.2	0.0	1.2
I don't know	26.3	6.9	44.0	44.4	54.5	36.4

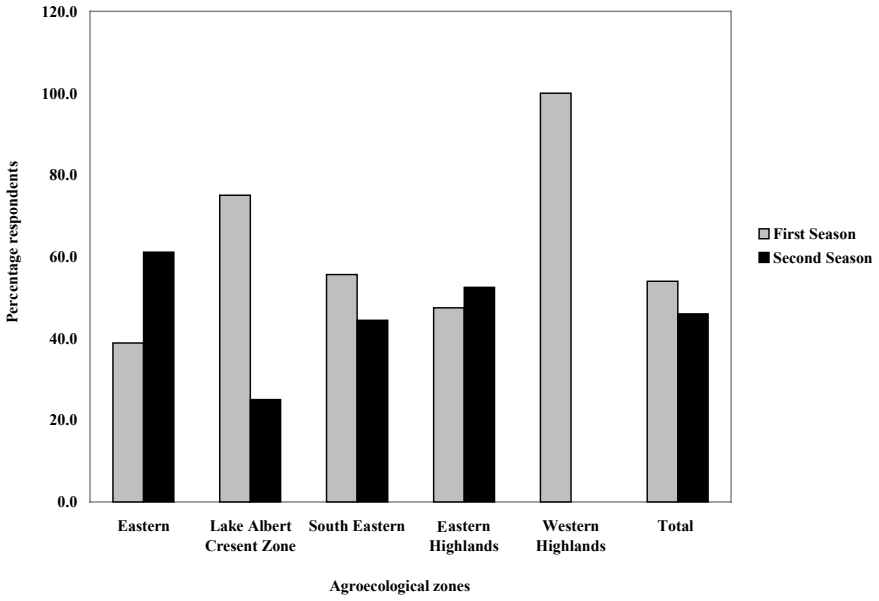

Figure 3: Farmers' perception of season when high Maize Lethal Necrosis disease incidence is experienced

Table 7. Percentage of farmers who had attempted to control Maize Lethal Necrosis disease

Have you attempted to control the disease?	Agroecological zone					Mean (n=152)
	Eastern (n=18)	Lake Albert Crescent Zone (n=29)	South Eastern (n=24)	Eastern Highlands (n=71)	Western Highlands (n=10)	
Yes	77.8	62.1	41.7	57.7	10.0	55.3
No	22.2	37.9	58.3	42.3	90.0	44.7

zone and 57.7% in Eastern highlands agroecological zone attempted to control the MLND unlike in the South eastern and Western highland agro-ecological zones where most respondents represented by 90.0% and 58.3% for the Western highland and South eastern agro-ecological zones reportedly did not attempt to control MLND (Table 7).Overall most respondents (77.4%) managed MLND through uprooting the diseased plants or roguing (Table 8). This is in agreement with findings by Kagoda *et al.,* 2016 who reported that roguing is the most popular means farmers in eastern Uganda are using to control MLN. Roguing is one of the methods that has been recommended for managing MLND (Wangai *et al.,* 2012b; Mawishe and Chacha, 2013; CIMMYT, 2013). Removal of diseased plants is reported to reduce a pathogen from infected areas before it becomes well established (Maloy, 2005). Hence these findings are encouraging since through use of roguing, the results suggest farmers already have a head start in the fight against this disease and what is required is to integrate such cultural practices with other management packages like use of insecticides as recommended by Nelson *et al.* (2011). The Eastern agro-ecological zone had the highest percentage using chemicals to control MLN (Table 8). However, the use of chemicals has been reported insufficient in the management of plant virus diseases (Satapathy, 1998; Perring *et al.,* 1999) which calls for adoption of integrated approach as earlier emphasised.

Overall most respondents (64.3%) reported that the methods used to control MLND were effective while 35.7% reported that the methods used were not effective (Table 9). This is probably because the disease is still relatively new in Uganda with low yield losses, low incidence and severity which can easily be managed through roguing before it becomes established.

As regards the effectiveness of specific methods used to control MLND, all farmers (100%) that selected disease free planting materials reported it to be effective (Table 10). Of the farmers that uprooted diseased, plants 60% of them reported it to be effective but 40% reported that it was not effective. Of those that burnt infected plants, the majority (71.4%) reported it as an effective method, while those that used pesticides most (85.7%) reported it as an effective method against MLND.

Table 8. Methods used to manage Maize Lethal Necrosis in different agro-ecological zones in Uganda

Methods used to control the disease	Agroecological Zone					Total (n=84)
	Eastern (n=14)	Lake Albert Crescent Zone (n=18)	South Eastern (n=10)	Eastern Highlands (n=41)	Western Highlands (n=1)	
	% farmers	% farmers	% farmers	% farmers	% farmers	% farmers
Selected disease free planting materials	7.1	0.0	0.0	9.8	0.0	6.0
Uproot diseased plants	71.4	72.2	100.0	75.6	100.0	77.4
Burnt infected plants	0.0	22.2	0.0	7.3	0.0	8.3
Spraying Using Pesticides	21.4	5.6	0.0	7.3	0.0	8.3

Table 9. Farmers' response (%) on whether control methods have been effective against Maize Lethal Necrosis disease

Have control methods been effective?	Agro ecological zone					Total (n=84)
	Eastern (n=14)	Lake Albert Crescent Zone (n=18)	South Eastern (n=10)	Eastern Highlands (n=41)	Western Highlands (n=1)	
Yes	57.1	88.9	80.0	51.2	100.0	64.3
No	42.9	11.10	20.0	48.8	0.0	35.7

Table 10. Farmers response (%) on effectiveness of specific methods used to control Maize Lethal Necrosis disease

Effectiveness of control method	Methods used to control the disease				Total (n=84)
	Selected disease free planting materials (n=5)	Uproot diseased plants (n=65)	Burnt infected plants (n=7)	Spraying using pesticides (n=7)	
Yes	100.0	60.0	71.4	85.7	65.5
No	0.0	40.0	28.6	14.3	34.5

Source of information about how to control the maize lethal necrosis disease. The major source of information on how to control MLND according to 31.2% of respondents was neighbors (Table 11). Farmers tend to have more confidence in technologies and information obtained from colleagues. Access to agricultural information has been emphasized in many studies as one of the key ways to build farmers' confidence in decision-making, whereas a lack of it limits farmers' innovation (Genius *et al.,* 2006). Hence reliance of the majority of farmers for information from neighbors (31.2%), farmers organization (28.9%) and radio (26.6%) and suggests that most farmers in this study are exposed to different information sources. This implies that they have the potential to improve their decision-making processes in diagnosing and managing MLND. However other sources of information mentioned by respondents from key stakeholders included 6% from extension staff of the National Agricultural Advisory Service (NAADS) Ugandan government program, 4.8% National Agricultural Research Organization of Uganda (NARO) researchers and 2.5% from NGOs. Thus the public sector should involve farmers in developing and disseminating MLND control information if that is to be taken up.

Factors influencing farmers' knowledge of MLN disease. Understanding the factors that determine farmers' knowledge and perception of MLN disease is critical in designing appropriate intervention programmes. Table 12 presents Pearson product-moment correlation coefficient and effects of the factors influencing farmers' knowledge of MLN disease in the agroecological zones. Preliminary analyses were performed to ensure no violation of the assumption of normality. There was a significant positive relationship between farmers knowledge of MLND and number of varieties of maize seed grown ($r=0.149$, $n=396$, $p=0.003$), season when maize is grown ($r = 0.135$, $n= 396$, $p=0.007$), growing maize solely or in intercrop ($r = 0.123$, $n= 396$, $p=0.014$), growing maize in rotation ($r =0.188$, $n= 396$, $p=0.001$), use of fertilizers ($r = 0.173$, $n= 396$, $p=0.001$) and presence of pest or disease attack ($r = 0.151$, $n= 396$, $p=0.003$) (Table 12). There was a statistically significant ($p<0.05$) negative relationship between farmers knowledge of MLND and household size ($r=0.176$, $n=396$, $p=0.001$), main land use ($r=-0.150$, $n=396$, $p=0.003$), reason for selecting a variety ($r= -0.109$, $n=396$, $p=0.030$), month of planting in season one ($r = -0.143$, $n= 381$, $p=0.005$) and major diseases noticed ($r = -0.393$, $n= 258$, $p=0.001$). There was no statistically significant ($p<0.05$) relationship between farmers awareness levels of MLND and key socioeconomic factors including gender, education level, age and land size, time of planting maize in first season, respondent age, years of growing maize, source of seed, acreage of maize grown, yield of maize, size of land owned, month of planting maize in second season, types of crops intercropped with maize, types of crops grown in rotation with maize, main types of pests, pest control method, major weed constraint and method of weed control. This implies that in designing maize lethal necrosis control packages the critical factors to consider are type of maize variety grown, variety attributes preferred, season of growing maize, time of planting maize during first season, cropping system sole vs intercrop, rotation of maize, fertilizer use, presence of pest and disease constraints and type of disease constraint experienced.

Table 11: Source of information about how to control the maize lethal necrosis disease

Where did you get information about how to control the disease	Eastern (%)	Lake Albert) Crescent Zone (%)	South Eastern (%)	Eastern Highlands (%)	Western Highlands (%)	Total (%)
Radio	21.4	15.4	10.0	35.7	0.0	26.6
Neighbors	50.0	46.1	40.0	17.7	100.0	31.2
Farmers Organization	21.4	7.7	30.0	37.8	0.0	28.9
NAADS Extension Staff	0.0	15.4	10.0	4.4	0.0	6.0
NARO Researchers	0.0	7.7	10.0	4.4	0.0	4.8
NGO	7.2	7.7	0.0	0.0	0.0	2.5

Table 12: Analysis of Association between farmers awareness levels of Maize Lethal Necrosis disease and socioeconomic and agronomic factors

	Farmers awareness levels of Maize Lethal Necrosis disease		
Socioeconomic and agronomic factors	Pearson Correlation, r	P value	n
Respondent gender	0.004	0.931	396.000
Education level	-0.054	0.287	396.000
Respondent age	0.040	0.426	396.000
House hold size	-0.176**	<0.001	396.000
Land size (Acres)	-0.010	0.841	396.000
Main land use	-0.150**	0.003	396.000
Why people grow maize	-0.028	0.573	396.000
Farming experience in growing maize (years)	0.003	0.947	396.000
Number of source of seed	-0.029	0.561	396.000
Number of varieties of maize grown	0.149**	0.003	396.000
Reason for selecting a maize variety to plant	-0.109*	0.030	396.000
Season when maize is grown	0.135**	0.007	396.000
Month of planting in season one	-0.143**	0.005	381.000
Month of planting in season two	-0.025	0.659	323.000
Grow maize solely or intercrop	0.123*	0.014	396.000
Main intercrops	0.011	0.864	254.000
Grow maize in rotation	0.188**	<0.001	396.000
Number of crops grown in rotation with maize	-0.075	0.247	241.000
Level of fertilizers use	0.173**	<0.001	396.000
Mode of harvest	0.074	0.139	396.000
Any pest or disease attack	0.151**	0.003	396.000
Major pests noticed	-0.035	0.507	352.000
Major diseases noticed	-0.393**	<0.001	258.000
Pest control method used	-0.036	0.496	359.000
Method of weed control	0.018	0.724	395.000
**. Correlation is significant at the	0.01 level		
*. Correlation is significant at the	0.05 level		

Source: Survey data of farmers in the five agroecological zones

CONCLUSIONS

This study has provided insight into the perception and management of MLND by farmers from main maize production districts in five agro-ecological zones of Uganda. Farmers' knowledge of MLND and the ability to diagnose the symptoms was varied and the majority of farmers did not know the causes of the disease. Emphasis should be on accurate disease diagnosis of the dusease. This study revealed that all maize varieties were susceptible to the disease. Therefore the absence of resistant genotypes is an indication of the need to breed and release MLND resistant varieties to farmers. Farmers' organizations, farmer neighbors and radios had the greatest contribution to farmers' awareness of MLND; there is hence need to integrate these sources with efforts from government agencies like the National Agricultural Advisory Service (NAADS) and the National Agricultural Research Organization of Uganda (NARO) in sensitization of farmers about MLND. According to respondents who experienced MLND, they successfully attempted to control it through roguing. This approach needs to be evaluated as a sustainable approach and also incorporate it with other known effective control methods. As regards factors influencing knowledge of MLND, this study revealed that maize variety grown, variety attributes preferred, season of growing maize, time of planting maize during first season, cropping system sole vs intercrop, rotation of maize, fertilizer use, presence of pest and disease constraint and type of disease constraint experienced were correlated with farmer knowledge of MLND. These findings will be important in designing appropriate intervention programmes.

RECOMMENDATIONS

Overall the majority of the respondents reported that MLND was higher during the first season than in the second season but this varied with agroecological zones. There is need to incorporate this knowledge in integrated management of MLND through developing simple decision aids targeting specific agroecological zones. Moreover, due to differences in weather patterns, studies are needed in Uganda to verify these findings and also determine effect of climate changes on the MLND disease prevalence. Thus, there is need to exploit this information on prevalence of the disease in different seasons and agro-ecological zones as part of a management strategy for the disease.

Since farmers in the study lacked adequate knowledge in diagnosis and causes of this disease, training on diagnosis, biology and ecology of this important disease can help farmers make informed crop management decisions. Overall, in designing an integrated maize lethal necrosis control package, the critical factors to consider are types of maize varieties grown, varieties attributes preferred, season of growing maize, time of planting maize during first season, cropping system sole vs intercrop, rotation of maize, fertilizer use, presence of pest and disease constraints and type of disease constraint experienced. The integration of the above agronomic management package should fit within the farmers' farming systems.

ACKNOWLEDGMENTS

Financial support from the National Agricultural Research Organization of Uganda through the Agricultural Technology and Agribusiness Advisory Services Project is gratefully acknowledged. We thank District Agricultural Officers and farmers in the target districts for the information used in this study.

STATEMENT OF NO CONFLICT OF INTEREST

We the authors of this paper hereby declare that there are no competing interests in this publication.

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