Maize lethal necrosis disease: Investigating Risks and Pre-emptive Management in West Africa

By

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Importance of Maize in Nigeria and Justification

Maize (*Zea mays* L.) is one of the major cereal crops in different agro-ecological zones of Nigeria (Iken and Amusa, 2004). Maize is consumed by humans and also forms an important feed element for livestock feeds. In addition, it has a lot of applications in the agro-based industries. It is an integral component of the traditional cropping systems in the country. Nigeria with an annual production of close to 8 million metric tonnes in 2013 is the largest producer in Africa. Maize is the third most widely grown crop in Nigeria, following sorghum and millet. Maize is highly productive, cheap, less rigorous to produce and adapts to wide range of agro ecological zones (Babatunde *et al*., 2008). Besides, the popularity of maize is not limited to the value of its output but also based on the number of farmers that produced it, as well as for its economic value (Olaniyi and Adewale, 2012). An estimated 5.2 million hectares were harvested in 2013 with an average yield of 2 mt ha/ha. In Nigeria, the increase in maize production from 1961 to date has been largely attributed to increase in land area cultivated (Table 1).

An understanding of the spread and associated yield reduction induced by spread of MLND would contribute in a way for effective control. This will ultimately result in high productivity and food insecurity would be minimal. Because of the possibility of identifying MLND-resistant or tolerant maize varieties that are locally adapted and high-yielding insecticidal control of the insect vectors would be reduced. This would reduce chemical health hazards to farmers, residual effects on the crops and consumers, environmental contamination and destruction of beneficial insects.

Maize Production Agro-ecologies and Planting Seasons in Nigeria

The greatest quantity of green maize comes from the rainforest agro-ecological zone of Nigeria while the savanna zone in northern Nigeria which consists of Derived Savanna, Guinea Savanna and Sahel agro-ecological zones account for substantial quantity of the pod (Ogunlade *et al*., 2010). Although large proportion of the green maize is still produced in the south-Western part of the country, there has been a conspicuous shift of dry grain production to the savanna, especially the Northern Guinea savanna. This agro-ecological zone is now regarded as the maize belt of Nigeria. In the zone, farmers prefer maize to sorghum owing to several reasons including availability of streak resistant varieties for all ecological zones in Nigeria, availability of high-yielding hybrid varieties, increase in maize demand coupled with the federal Government imposed ban on importation of rice, maize and wheat. Local production had to be geared up to meet the demand for direct human consumption, breweries, pharmaceutical companies, baby cereals, livestock feeds and other industries (Iken and Amusa, 2004). Some of the major maize-producing States in the savanna zone of Nigeria include Benue, Kogi, Kwara, Niger, Kaduna, Kano, Katsina and Plateau.

Planting dates and the number of times the crop can be grown within the cropping season vary according to agro-ecological zone (Table 2) (Iken and Amusa, 2004). The major organizations involved in maize improvement and protection in Nigeria include Institute of Agricultural Research and Training (IAR&T), Osun State; Institute for Agricultural Research (IAR), Zaria, Kaduna State; National Agricultural Extension Research and Liaison Services (NAERLS) of Ahmadu Bello University, Zaria, Kaduna State; National Agricultural Seed Council (NASC), Abuja; and the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State.

Table 1. Maize production statistics for Nigeria from 1961 – 2013

Year	Area harvested (ha)	Yield (kg/ha)	Production (tonnes)
1961	1375000	8051	1107000
1962	1120000	8848	991000
1963	1140000	10237	1167000
1964	1471000	7600	1118000
1965	1404000	8262	1160000
1966	1145000	8515	975000
1967	1163000	8169	950000
1968	1095000	10283	1126000
1969	1371000	9154	1255000
1970	1449000	9959	1443000
1971	1218000	10460	1274000
1972	1115000	5731	639000
1973	1246000	6485	808000
1974	579000	9119	528000
1975	971000	13718	1332000
1976	892000	11973	1068000
1977	610000	10656	650000
1978	519000	12678	658000
1979	425000	11482	488000
1980	465000	13161	612000
1981	438000	16438	720000
1982	556000	13777	766000
1983	1058000	9707	1027000
1984	1050000	11390	1196000
1985	1556000	11735	1826000
1986	2800000	12679	3550000
1987	3408000	13533	4612000
1988	3212000	16401	5268000
1989	3590000	13950	5008000
1990	5104000	11301	5768000
1991	5142000	11299	5810000
1992	5223000	11181	5840000
1993	5309000	11848	6290000
1994	5426000	12720	6902000
1995	5472000	12666	6931000
1996	4273400	13261	5667000
1997	4200000	12510	5254000
1998	3884000	13200	5127000
1999	3423000	15998	5476000
2000	3159000	13001	4107000
2001	3283000	13999	4596000
2002	3282000	14899	4890000
2003	3469000	14999	5203000
2004	3479000	16002	5567000
2005	3589000	16598	5957000
2006	3905000	18182	7100000
2007	3944000	17049	6724000
2008	3845000	19571	7525000
2009	3350560	21961	7358260
2010	4149310	18502	7676850
2011	6008470	15279	9180270
2012	5200000	18096	9410000
2013	5200000	20000	10400000

Source: FAO (2013)

Table 2. Maize seasons in different agro-ecological zones of Nigeria

S/No.	Agro-ecological zone	State (s)	Season 1	Season 2
1	Forest	Akwa-Ibom, Cross River, Lagos	Mid April to 2nd week in May	July to August
2	Forest - Savanna transition	Oyo, Edo	3rd week in April to 3rd week in May	July to August
3	Southern Guinea Savanna	Kwara, Niger	Las week in April to 3rd week in May	July to August
4	Northern Guinea Savanna	Kaduna, Niger	Last week in May to 1st week in June	
5.	Sudan Savanna	Kano, Katsina	First two weeks in June	

Major Maize Seed Companies in Nigeria

The major maize seed companies in Nigeria include Premier Seed Ltd in Zaria, Kaduna State. This is the largest seed company in the country, founded in 1989 as Parental Line Seed Limited, which merged with the Pioneer Hi-bred Seed Company of the USA in 1990. Premier produces its own inbred lines for hybrid maize. It also produces seed of open pollinated variety (OPV) maize. Others include Agricultural Seed Nigeria Limited (AgSeed), founded in 1984 by the Leventis Foundation; and Romarey Seeds Venture Nigeria Limited located in Jos, Plateau State

Maize Production Constraints

Despite the annual increase in area under production, yield per hectare for maize in Nigeria is as low as 2.0 mt ha^{-1} far lower than world average which is 5.1 mt ha/ha. This could be attributed to biotic and abiotic factors. Abiotic factor includes poor soil fertility, inadequate physical infrastructure, and poor resources (Ibrahim *et al.*, 2014). The major biotic constraints to maize production includes insect pests and disease attack (Table 3)

Table 3. Major insect pests and diseases of maize in Nigeria

S/No.	Insect pests	Reference (s)
1	Maize borers (*Busseola fusca* Fuller)	Daramola (1991)
2	Armyworm (*Spodoptera exempta* Walker)	Ditto
3	Silkworm (Bombyx mori L.)	Ditto
4	Grasshopper (*Zonocerus variegatus* L.)	Ditto
5	Termites (*Odontotermes smeathmani* Fuller)	Ditto
6	Weevil (*Sitophilus zeamais* Motsch)	Ditto
	Diseases	
1	Maize rust	Fajemisin et al. (1976); Oladipo et al. (1993)
2	Leaf blight	Ditto
3	Curvularia leaf spot	Ditto
4	Downy mildew	Ditto
5	Stalk & ear rots	Ditto
6	*Maize streak virus*	Ditto
7	*Maize mottle| Chlorotic stunt*	Ditto

Maize Lethal Necrosis outbreak in Africa

Maize lethal necrosis disease (MLND), first reported in 2011 in Kenya, is a new viral disease in Africa that devastated maize production reducing yields by 30 to 100 % in the affected farms (Wangi *et al*., 2012). This disease has since spread to Uganda, Tanzania, Rwanda and South Sudan. Great risk exists for further spread within Africa.

MLND is a synergistic disease caused by co-infection of *Maize chlorotic mottle virus* (MCMoV, genus *Machlomovirus*) and *Sugarcane mosaic virus* (SCMV, genus *Potyvirus*) (Jiang *et al*., 1992). However, other potyviruses, such as *Maize dwarf mosaic virus* and *Wheat streak mosaic virus*, can also interact with MCMoV in causing MLND. Single infection of any of these viruses does not lead to lethal necrosis. MCMoV is transmitted by thrips and beetles, whereas potyviruses are transmitted by aphids. Low rate (1:2500) of MCMoV transmission through seed has also been reported (Jensen *et al*., 1991). Although, this is yet to be proven for African MCMoV isolates, but seed-transmission represents a means for long distance virus spread in the continent.

Sustainable MLND control requires a thorough understanding of its epidemiology, potential vectors, virus strains and identification of resistant sources. In Eastern Africa studies are already on-going to understand and curb the MLND menace but such attempt has not been initiated in West and Central Africa. Spread of MCMoV can trigger onset of MLND epidemics in any region due to the ubiquitous occurrence of complimenting potyviruses and insect vectors.

Nigeria has been selected because it is a major maize–producing country in Africa. Selected states represent diverse agro-ecologies and farming systems, and represent a typical cross section of maize cultivating zones for assessing virus and vector diversity. Additionally, Nigeria as a principal maize-growing country in Africa (IITA, 2013) is surrounded by Chad and Cameroon which serve as a link between West and Eastern Africa countries (where MLND has been confirmed). Because the disease is transmitted by

insect vectors, trans-border spread of MLND is not impossible. Therefore, a survey of some Nigerian states sharing border with the aforementioned countries would provide information on the incidence and severity of the disease. This information also could serve as a basis for further investigation of the prevalence of MLND in other West African countries.

Specific objectives

This project was conducted to:

1. Determine the incidence and diversity of potyviruses (e.g. SCMV) with potential to interact synergistically with MCMoV in causing MLND.
2. Identify occurrence and diversity of potential vectors of MLND prevalent in Nigeria.
3. Establish a phenotyping system for evaluating maize germplasm for SCMV resistance.
4. Establish capacity to diagnose MLND and its causal agents in Nigeria.
5. Create awareness about MLND.
6. Develop linkages with MLND control programs in East Africa for information sharing and augmenting control efforts

The investigation was expected to provide vital information on the risks and development of pre-emptive control measures. West and Central African breeding program of IITA, and several commercial seed companies are based in Nigeria that have active international seed exchange programs. Spread of MLND can prove catastrophic in Nigeria and in West African sub-region. Outputs of this project would contribute to preparedness and prevention of MLND pandemic extendable to other countries in West and Central Africa.

Materials and Methods

A survey protocol was developed and used for field assessment for virus diseases. Surveys were conducted in the following states during the early season: Akwa-Ibom and Cross Rivers (25th April – 7th May, 2014); Kaduna, Kano and Niger (6 – 15 August, 2014). A follow up survey was conducted in the following states during the late season: Niger (26th September – 1 October, 2014); Ogun, Osun and Oyo (3rd – 16th October, 2014). In addition, surveys were conducted in Kwara, Niger and Ogun States from 6th – 19th November, 2014. Fields were surveyed when plants were at the mid reproductive phase (*ca.* 10 weeks after sowing). Information on each field was captured using the Data Collection Sheet. This basically includes the date and time of visit, field size, cropping system, crops in neighbouring fields, etc. The geographical coordinates/positioning of each field was obtained using a Global Positioning System (GPS), for virus distribution map.

In each site, between twenty and thirty plants were examined for general disease symptoms along intersecting field diagonals. Symptom types and severity (on a scale of 1 to 5, where 1 means mild infection and 5 represents severe disease condition) were recorded. In addition, photographs were taken of plants with varied morphological dispositions, including healthy ones. For each field, disease incidence was determined as the percentage of plants with at least a severity score of 2. Disease severity range and mean were also computed. Leaf samples collected were preserved over silica gels in vial bottles until analyzed. Leaf samples were tested for for MCMV, SCMV and potyviruses using Enzyme-Linked Immunosorbent Assay (ELISA) and Polymerase Chain Reaction (PCR). Altogether, 1438 samples were assayed. The data obtained have been used to generate MSV distribution map.

Enzyme-Linked Immunosorbent Assay (ELISA) Protocols

Samples were subjected to serological test using the standard laboratory Antigen coated plate (ACP) Enzyme Linked immunosorbent Assay procedure. One hundred µL of individual saps were loaded into microtitre plates and was incubated for 1 hr at 37^0 C. Plates were washed using PBS-T thrice and tap dried. One gram of healthy maize leaf was ground in 20 mL conjugate buffer in order to get rid of all host protein i.e. 1:20 (w/v) and was incubated for 30 min at 37^0 C just after the addition of MSV and MCMV antibodies at 1:10,000 dilution each, which was later added to the plate and was re-incubated. Plates were washed and tap dried 1 hr after incubation. 1:15,000 dilution of goat anti rabbit enzyme was subsequently added to individual plates and re-incubated. Finally, 1:10,000 dilution of substrate buffer was prepared and dispensed and was kept in a dark chamber for colour reaction. Readings were taken both at 1 hr and overnight and data were analyzed by multiplying the healthy value by two and comparing with surveyed samples.

Procedure for the extraction of nucleic acid and virus indexing

Five leaf tissues were selected per field for the extraction of total nucleic acid using CTAB protocol. Sample selection was based on severity scores, giving highly infectious plants priority. One hundred milligram each of the collected leaf sample was ground thoroughly using sterile mortal in 10 volumes (1 ml) of CTAB buffer (2% CTAB (w/v), 1.4M NaCl, 0.2% 2-mercaptoethanol (v/v), 20mM EDTA, 100 mM Tris–HCl, pH 8.0). 750µL of each sample was transferred to a 1.5 ml eppendorf tube, mixed and incubated in a water bath at 60 ^{0}C for 10min. The extract was mixed with an equal volume (750µLl) of phenol: chloroform: isoamyl alcohol (25:24:1), mixed thoroughly and centrifuged at >12,000×g for 10 min. The supernatant was transferred to a new 1.5 mL eppendorf tube and nucleic acid was precipitated by adding 0.6 volumes (300µl) of ice cold (-20^0C) isopropanol.

Samples were then incubated at -20^0C for 1 hr and centrifuged finally at 12,000×g for 10 min at 4^0 C. The pellet was washed in 0.5 ml 70% ethanol, centrifuged for 5 min and air dried. The pellet was finally dissolved in 50 µl of sterile distilled water and stored at -20^0 C. The detergent CTAB was also added in order to aid the release of DNA into the extraction buffer and to protect the DNA from endogenous nucleases. The additive EDTA (ethylene diamine tetra acetic acid) which served as chelating agent was also added as acofactor to bind magnesium ions. The phenol-chloroform was used to denature and separate the proteins from the DNA in the buffer- tissue mixture. A pH of 8.0 was maintained since at lower pH DNA is selectively retained in the organic phase leaving the RNA in the aqueous phase. Suspended DNA samples were then diluted at 1:50v/v (stock DNA solution: sterile distilled water) and were used to set up PCR using the following set of reagents for the preparation of cocktail.

Ten pmol each of the primers, 5× GoTaq green reaction buffer (10mM Tris-HCl (pH 8.8), 50 mM KCl, 1.5 mM $MgCl_2$, 0.01% Triton-X 100), 10 mM each dNTPs, 25mM $MgCl_2$, and 0.3 units Taq DNA polymerase. PCR was carried out in a 96-well Applied Biosystem Veritti Thermalcycler (Applied Biosystems Inc., USA) with the following thermocyclic conditions
44^0C for 30 min,

94^0C for 1 min
52^0C for 2 min
72^0C for 3 min
94^0 C for 1 min
54^0C for 2 min 35 cycles

72^0C for 1 min 33 sec
72^0C for 5 min

This was used for the detection of Potyvirus while the following thermocyclic condition was used for the detection of multiple viruses (*Maize streak virus* (MSV), *Maize chlorotic mottle virus* (MCMV) *and Sugarcane mosaic virus* (SCMV).
42^0C for 30 min,
94^0C for 3 min
94^0 C for 30 sec
54^0C for 30 sec 40 cycles
68^0C for 1 min
72^0C for 10 min

1.5 g of agarose powder was mixed with 100 mL of the electrophoresis buffer which was then heated in a microwave oven until completely melted. After cooling the solution to about 6 ^{0}C, it was poured into a casting tray containing a sample comb and allowed to solidify at room temperature. After the gel had solidified, the comb was removed, using care not to rip the bottom of the wells. The gel, still in its plastic tray, was inserted horizontally into the electrophoresis chamber and just covered with buffer. Samples containing DNA mixed with loading buffer were then pipetted into the sample wells, the lid and power leads were placed on the apparatus and a current was applied. DNA migrated towards the positive electrode, which is usually coloured red.

The distance of the DNA migration in the gel was judged by visually monitoring the migration of the tracking dyes. Bromophenol blue and xylene cyanol dyes migrated through the agarose gels at roughly the same rate as the DNA fragments. Finally, the gel was placed on the ultraviolet transilluminator for gel picture documentation. Gel pictures were subsequently used for the scoring of viruses as leaf samples that showed expected band sizes of 1304 bp, 500 bp and 900 bp for MSV, MCMV and SCMV, respectively were considered to be virus infected.

Results
In all the agro-ecologies surveyed majority of the farmers grew maize on less than 1 ha. of land. In the eastern part of the country although maize is cultivated twice annually most farmers preferred cassava as number one crop. Farmers confirmed that double cropping of maize was facilitated by the bimodal nature of rainfall. Maize was grown in mixtures with other principal food crops such as cassava, yam, sugarcane, banana and plantain, cocoyam, fluted pumpkin, okra, pepper etc. The neighbouring crops around maize were predominantly maize and cassava or cassava, yam and vegetables such as fluted pumpkin and okra.

All the farmers interviewed in Akwa Ibom and Cross River States testified that they usually purchased maize seeds from the market, however, actual variety names were not known. Similarly, they never used pesticides to control insect pests and diseases; they normally replenished tired soils through the application of poultry droppings and careful management of plant debris after harvesting. Some farmers confirmed the presence of some disease conditions on yearly basis but attributed such to low level of soil fertility. All the farmers interviewed were ready to acquire seeds from reliable sources such as research institutes, Agricultural Development Projects (ADPs), ministries of agriculture etc.

In Kaduna, Kano and Niger situated in the northern part of the country, rainfall is monomodal and maize is the principal cereal crop. In most instances maize was

intercropped with guinea corn or millet. The neighbouring crops around maize were predominantly maize, cowpea, soybean, guinea corn and vegetables.. Most farmers stated that they sourced for maize seeds from Research Institutes such as IITA, and ADPs. Some farmers attested to pesticide application only for weed control of insect pests in cowpea fields. Soil improvement is mainly through application of inorganic fertilizers (NPK and Urea). Some farmers also apply cow dung or poultry droppings on the farm in order to boost yield. There were farmers who confirmed the presence of some disease conditions on yearly basis. All the farmers interviewed were ready to acquire maize and sugarcane seeds/cuttings from reliable sources such as research institutes, ADPs, Ministry of Agriculture etc.

In south western Nigeria, rainfall peaks twice as in Akwa Ibom and Cross River States. Maize fields were surrounded by cassava, yam and vegetables. Farmers usually obtain seeds fro IITA, IAR&T (Institute of Agricultural Research and Training), ADPs and Ministry of Agriculture. Disease symptoms were generally mild or moderate to severe mottling. Some plants exhibited mosaic symptom, stunting, deformation and there were cases of plant death (Plate 1). By visual observation, disease incidence was highest in Gbako (63.3 %) Local Government of Niger State, whereas the lowest was observed in Owode (7.1 %) Local Government Area of Osun State. In ELISA and PCR tests none of the samples tested positive to SCMV or MCMV. However, about 19 % of the samples tested positive to *Maize streak virus* (Fig. 1 – 10 and Table 3) an endemic virus in Nigeria and several parts of Africa. The data in Table 1 also reveal that MSV incidence was highest in Kano State (45.7 %) while the lowest was recorded in Cross River State (8.3 %).

Plate 1. Representatives of the diverse symptoms observed on maize and sugarcane plants during the surveys of Rainforest and Savanna agro-ecological zones of Nigeria in 2014

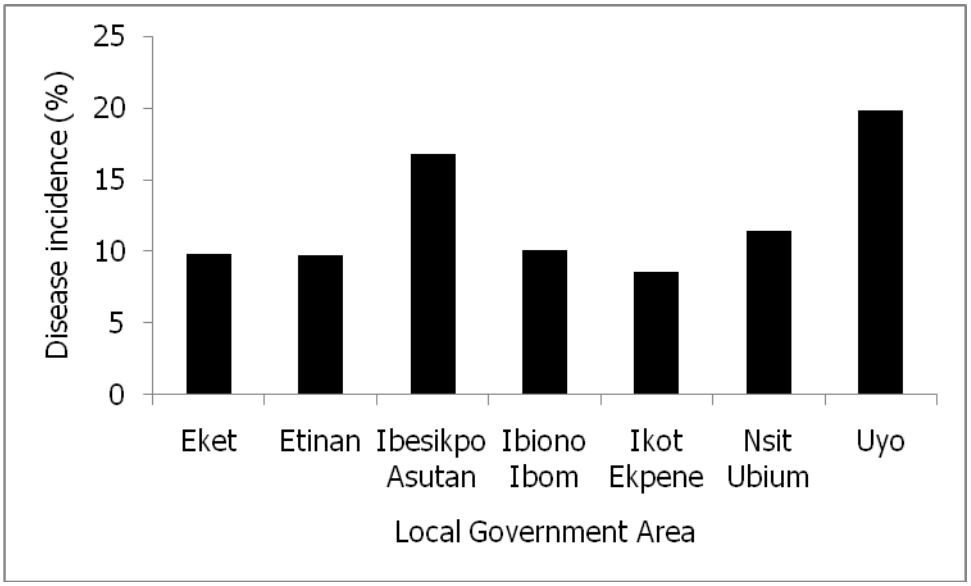

Fig. 1: Incidence of virus diseases in different Local Government Areas of Akwa Ibom State, 2014

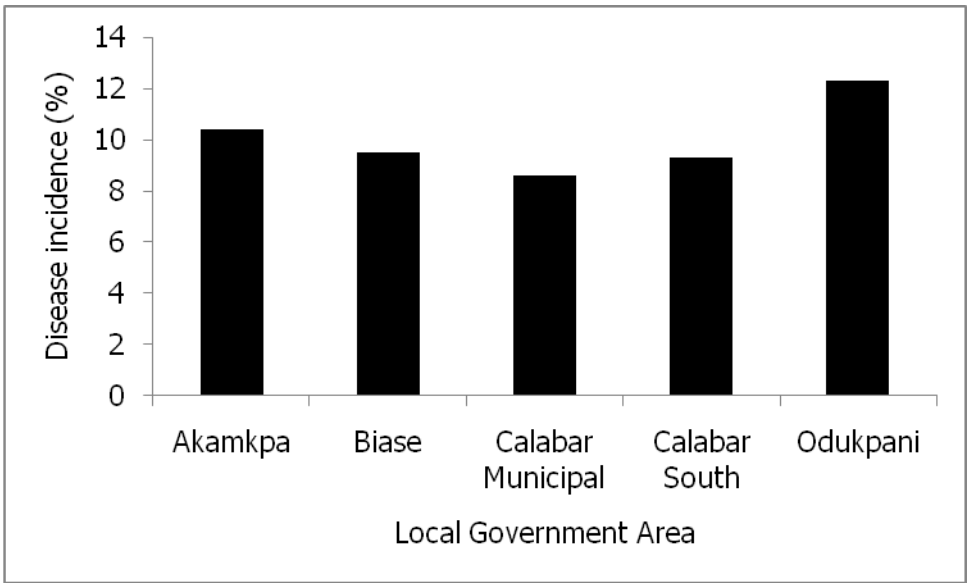

Fig. 2: Incidence of virus diseases in different Local Government Areas of Cross River State, 2014

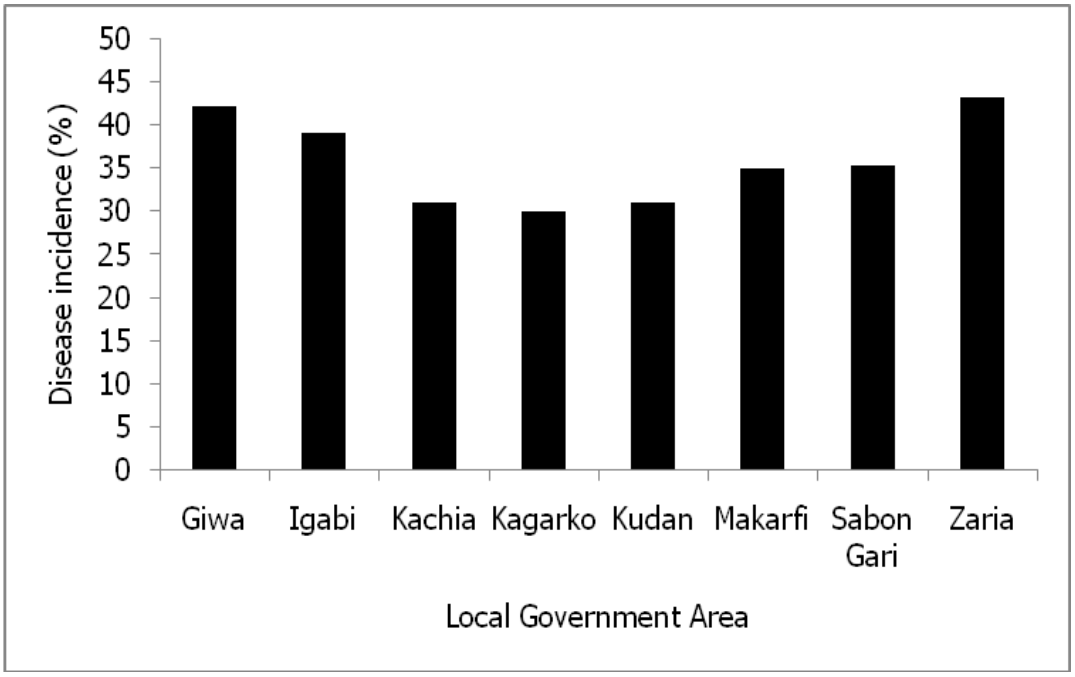

Fig. 3: Incidence of virus diseases from maize fields in different Local Government Areas of Kaduna State, 2014

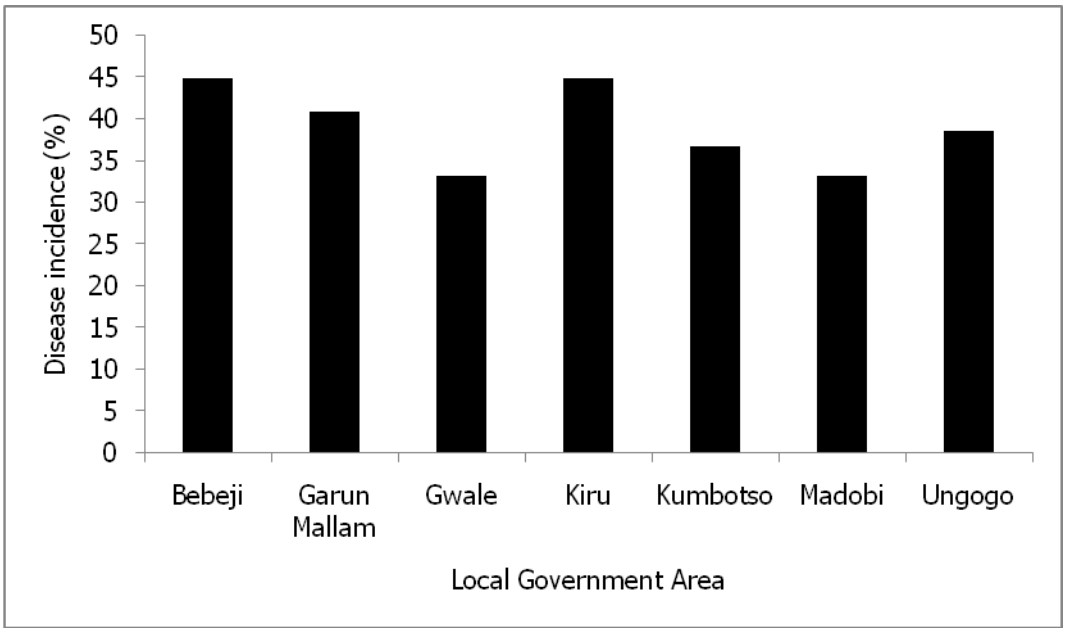

Fig. 4: Incidence of virus diseases from maize fields in different Local Government Areas of Kano State, 2014

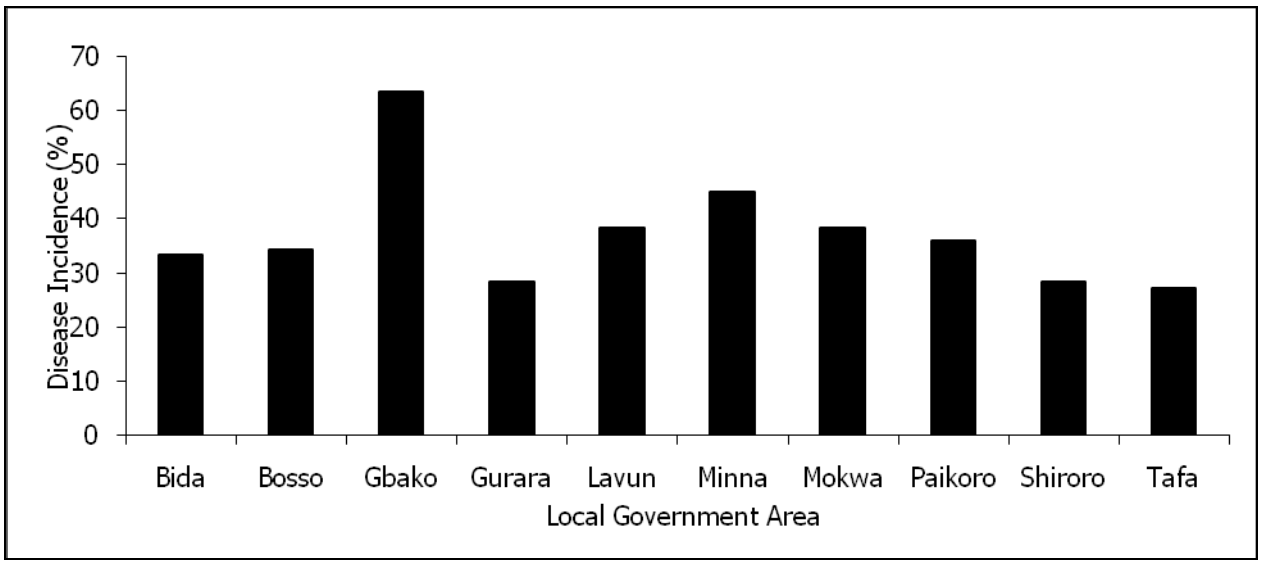

Fig. 5: Incidence of virus diseases from maize fields in different Local Government Areas of Niger State during the early cropping season (first survey), 2014

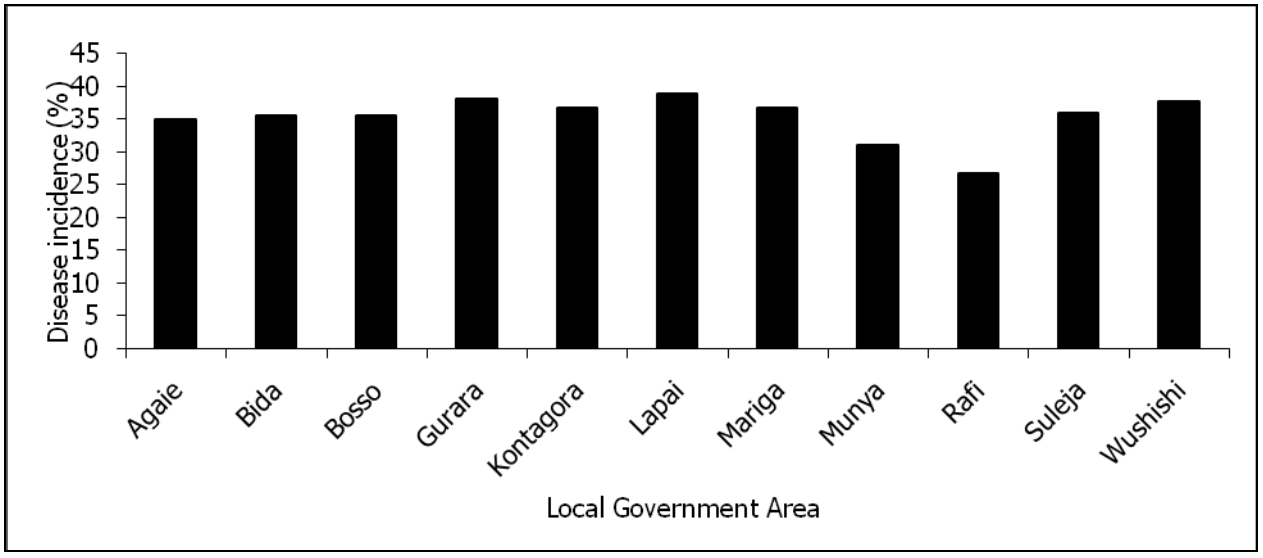

Fig. 6: Incidence of virus diseases from maize fields in different Local Government Areas of Niger State during the late cropping season (second survey), 2014

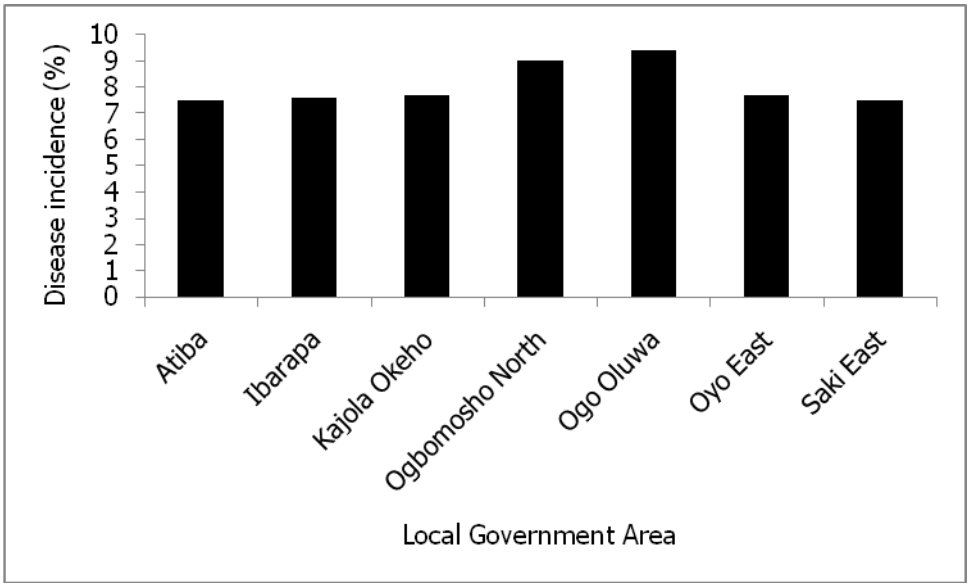

Fig. 7: Incidence of virus diseases from maize fields in different Local Government Areas of Oyo and Ogun States during the late cropping season (first survey), 2014

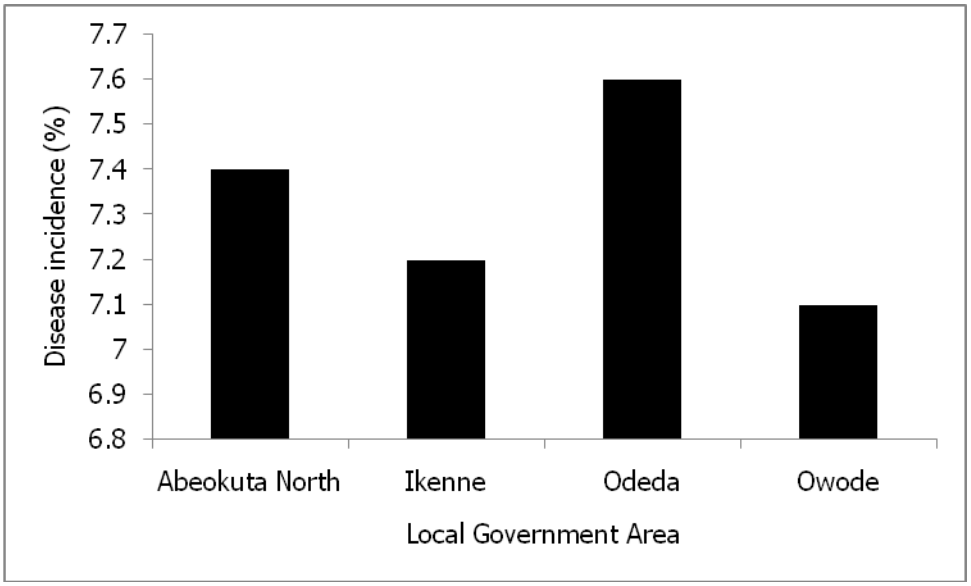

Fig. 8: Incidence of virus diseases from maize fields in different Local Government Areas of Ogun States during the late cropping season (first survey), 2014

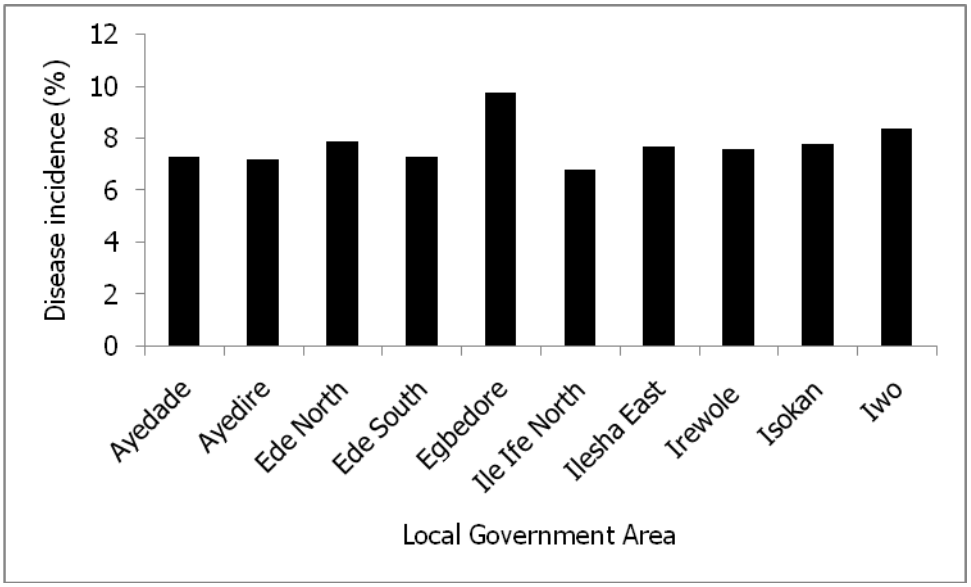

Fig. 9: Incidence of virus diseases from maize fields in different Local Government Areas of Osun State during the late cropping season, 2014

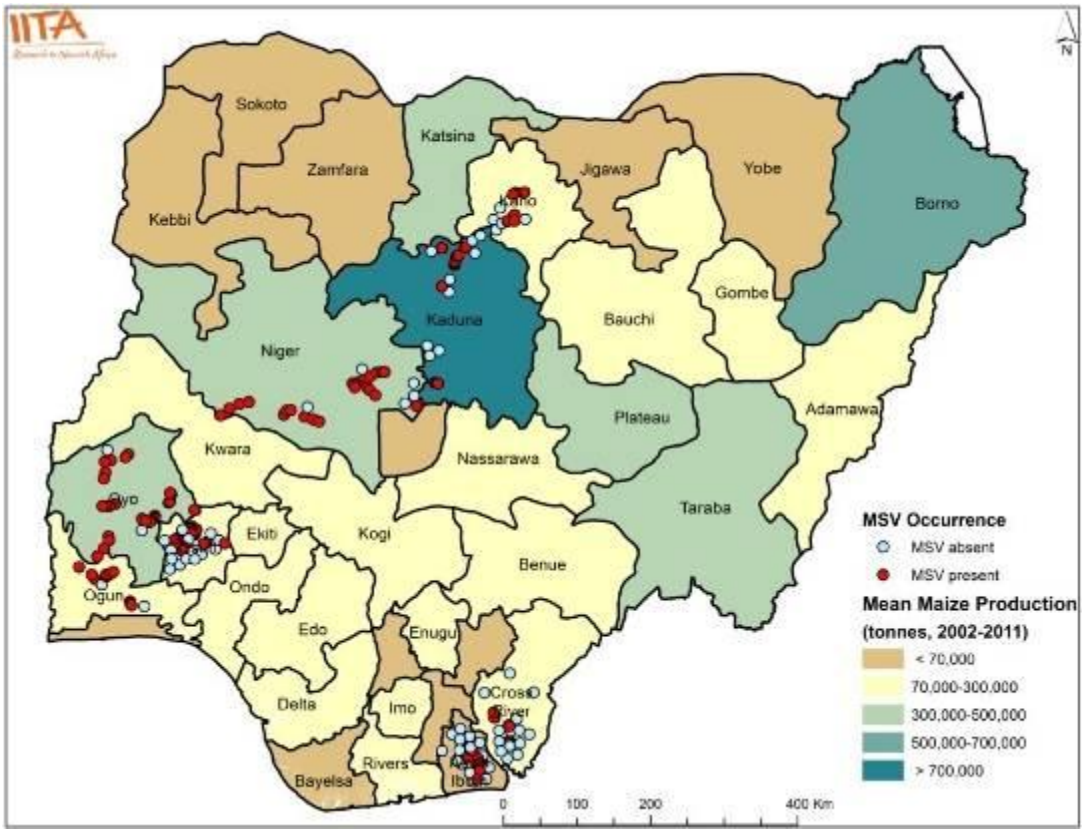

Fig 10. Survey locations and occurrence of maize streak disease from farmers' fields in 7 states of Nigeria.

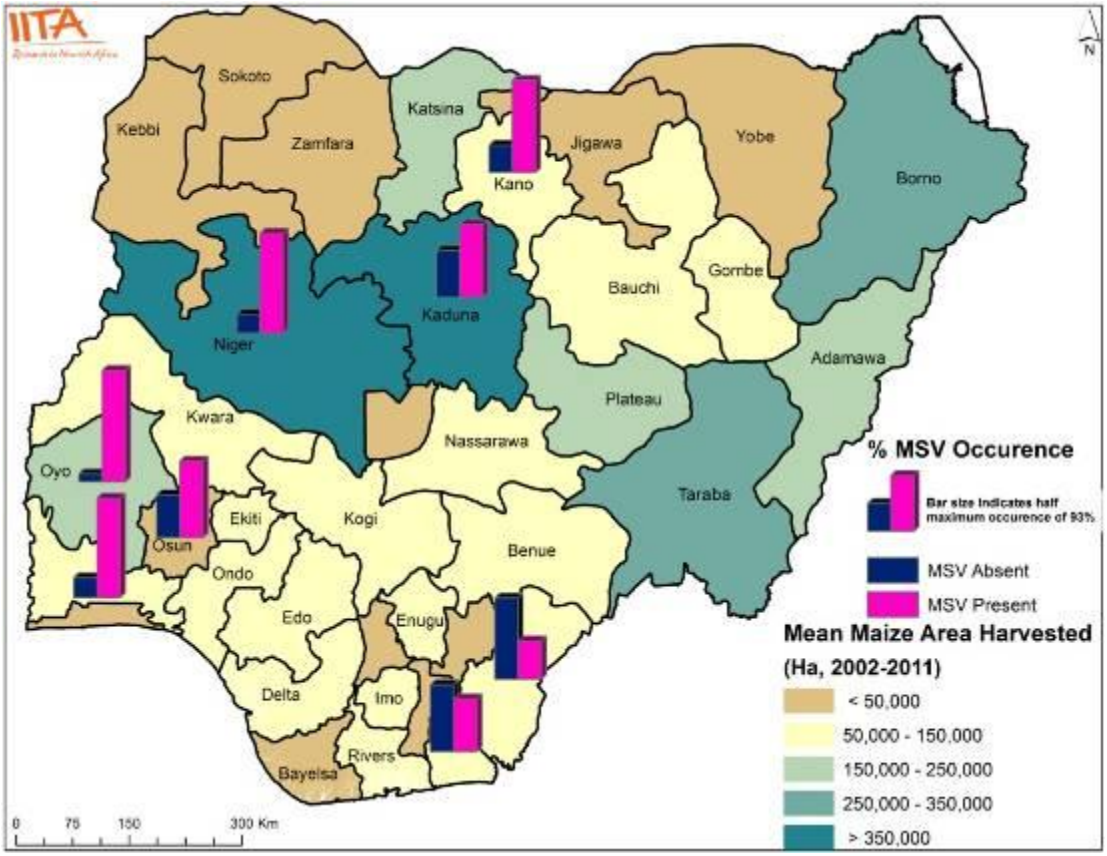

Fig 11. Percent *Maize streak virus* (MSV) occurrence from different states in Nigeria

Table 3: Reactions of maize and sugarcane leaf samples to MSV and MCMV in Enzyme-Linked Immunosorbent Assay (ELISA)

State of Nigeria	Total number of Maize samples indexed for virus	Total number of samples Negative to virus	Total number of samples Positive to virus	% MSV incidence	% MCMV incidence
AKW	609	553	76	12.5	0
CRS	408	374	34	8.3	0
NRS	123	77	46	37.4	0
KDS	50	31	19	38	0
KNS	35	19	16	45.7	0
OSS	89	58	31	34.8	0
OYS	89	52	37	41.6	0
OGS	35	22	13	37.1	0

*AKW- Akwa Ibom State, CRS- Cross River State, NRS- Niger State, KDS- Kaduna State and KNS- Kano State. OSS- Osun state, OGS- Ogun state and OYS- Oyo state.

Discussion

Several viruses cause significant reductions in maize in sub-Saharan Africa with attendant severe losses and threat to food security The detection of MSV in all the surveyed sites suggests the prevalence of the virus in Nigeria. This implies that the virus is endemic in the country. Hitherto, streak infection in maize was of little importance until 1970s. The prevalence of MSV disease could have been facilitated by a number of factors. Notable among them is the mode of spread. *Maize streak virus* is obligately transmitted by leafhoppers in a persistent manner (Alegbejo *et al*., 2002). Therefore, the infected plants become sources of primary inoculum and virus refuge to infect other plants. Because of the active nature of the vector infection is not usually restricted to the nearby plants but those in far distance are prone to infection risk.

The observation that farmers were not disposed to insecticide applications seems to have worsened the situation. However, even if adopted, investigations have revealed that the leafhopper vectors subsist on several alternative crop plants including weed species (Ouwafemi *et al*., 2011). Besides, application of insecticide is partially effective because the recurring influx of migrant hopper populations re-infect the crop after each application (Magenya *et al*., 2008). Low level of streak incidence was encountered in some maize fields due to late infection. The incidence of streak disease was high in the Forest and Forest – Savanna transition agro-ecologies due to bimodal nature of rainfall which encourages relay cropping of maize within the cropping seasons. In the Savanna agro-ecology, streak disease was prevalent probably because of the intensive cultivation. Iken and Amusa (2004) reported that maize production is now greatest in the Savanna agro-ecology of Nigeria. Unlike the Forest zone which is characterized by trees, the Savanna region is generally hone to grass plants which enable leafhopper vectors to survive between seasons. Besides, the observation that maize is commonly grown in mixture with guinea corn and millet was possibly responsible for high rate of infection because these crops are also important host plants for leafhoppers.

Weather is another factor which enhances leafhopper population. Disease incidence is particularly aggravated under favourable temperature. For instance Alegbejo *et al*. (2005) reported a significant positive correlation between leafhopper population and MSV disease incidence in the Savanna agro-ecology of Nigeria. Similarly there were reports of MSV disease epidemics in 1966, 1971, 1973, 1976, 1983 and 1984 (Eseman, 1966; Fajemisin and Shoyinka, 1976; Kim *et al*., 1981; Efron *et al*., 1989).

Streak severity was not uniform in the study area due to a number of reasons. As clearly confirmed, by the farmers most of them sourced seeds from open markets. This practice does not guarantee the use of streak-resistant/tolerant varieties. However, adoption of varieties with MSV resistance genes offers insurance against total crop failure. The differences in MSV disease severity was also variable as a result of differences in genetic architecture of the cultivars, plants' age at the time of infection, strain and virulence of the invading. Previous studies revealed that 11 strains of MSV have been confirmed from different parts of Africa and its neighbouring Island (Martin *et al.*, 2001; Schnippenkoetter *et al.*, 2001; Willment *et al*., 2002; Varsani *et al*., 2008; Oluwafemi *et al*., 2011). Therefore, these and the associated attributes probably contributed to the variation in the level of severity on the plants.

Conclusion and Recommendations

The results of this investigation show that MLND is not yet in Nigeria. Even in the States that have close proximity to the East African countries where the disease has reached an alarming rate, none of the samples tested for the viruses that perpetuate MLND. However, continuous surveillance is essential in order to forestall any eventuality. In the main time strategies which are currently in use in the countries where the virus has been confirmed are hereby recommended:

1. Adoption of good cultural practices such as crop rotation, crop diversification, conservation agriculture and timely weed control.
2. Judicious use of systemic and contact pesticides to control possible vectors of MLND.

3. Enforcement of local quarantine procedures at the borders.

4. Use of clean certified seed.

5. Application of manure, basal and top dressing fertilizers to enhance growth and development.

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Appendix 1. Survey for Maize and Sugarcane Viruses In Akwa-Ibom and Cross River States, 25 April - 7 May, 2014

Sl. No.	Field no.	State	LGA	Location	Longitude	Latitude	Altitude (m)	No of plants assessed	% symptomatic plants	Mean severity score	Insects
1	AKW 1	Akwa-Ibom	Ibesikpo Asutan	Nung Udoe	N04.94317	007.94474	52	30	23.3	1.6	2
2	AKW 2	Akwa-Ibom	Ibesikpo Asutan	Ikot Obiofom	N04.93730	007.95262	57	25	8.0	1.1	10
3	AKW 3	Akwa-Ibom	Ibesikpo Asutan	Owot-Uta	N04.94588	007.94765	58	30	6.7	1.1	None
4	AKW 4	Akwa-Ibom	Ibesikpo Asutan	Nung Udoe	N04.92083	007.96173	44	22	9.1	1.1	None
5	AKW 5	Akwa-Ibom	Ibesikpo Asutan	Ntokoton	N04.85972	007.98793	41	30	36.7	2	None
6	AKW 6	Akwa-Ibom	Nsit Ubium	Ikot Akpan Abia	N04.83582	007.96665	49	30	6.7	1.2	None
7	AKW 7	Akwa-Ibom	Nsit Ubium	Ndukpo Ise	N04.79982	007.96733	34	30	6.7	1.1	None
8	AKW 8	Akwa-Ibom	Nsit Ubium	Ndukpo Ise	N04.79307	007.96865	38	30	6.7	1.1	None
9	AKW 9	Akwa-Ibom	Nsit Ubium	Ndukpo Ise	N04.78805	007.96983	37	30	10.0	1.2	None
10	AKW 10	Akwa-Ibom	Nsit Ubium	Ikot Ekwere	N04.77827	007.97572	40	26	26.9	1.9	None
11	AKW 11	Akwa-Ibom	Eket	Eket	N04.64099	007.91701	27	25	12.0	1.4	None
12	AKW 12	Akwa-Ibom	Eket	Eket	N04.63913	007.91808	27	20	10.0	1.3	None
13	AKW 13	Akwa-Ibom	Eket	Ata Idung Afaete	N04.66671	007.97701	16	21	9.5	1.3	None
14	AKW 14	Akwa-Ibom	Eket	Ikot Uso Ekong	N04.67047	007.98065	56	25	8.0	1.2	None
15	AKW 15	Akwa-Ibom	Eket	Ikot Udoma	N04.66296	007.95171	24	21	9.5	1.1	None
16	AKW	Akwa-Ibom	Etinan	Ikot Obio Inyang	N04.96621	007.83978	72	22	13.6	1.4	None

	16										
17	AKW 17	Akwa-Ibom	Etinan	Ikot Obio Inyang	N04.96114	007.83998	53	21	9.5	1.1	None
18	AKW 18	Akwa-Ibom	Etinan	Mbioto 1	N04.93649	007.84071	62	21	9.5	1.1	None
19	AKW 19	Akwa-Ibom	Uyo	Nungo Uyo Idoro	N05.03009	007.87205	77	30	10.0	1.2	None
20	AKW 20	Akwa-Ibom	Uyo	Aka Road	N05.01780	007.52180	76	20	10.0	1.2	None
21	AKW 21	Akwa-Ibom	Uyo	Anna Obio	N05. 01182	007.88942	69	25	8.0	1.1	None
22	AKW 22	Akwa-Ibom	Uyo	Anna Obio	N05.01303	007.88970	70	23	52.2	3	None
23	AKW 23	Akwa-Ibom	Uyo	Atan Offot	N05.01863	007.89660	58	21	19.0	1.3	None
24	AKW 24	Akwa-Ibom	Ibiono Ibom	Ikot Osukpong	N05.06871	007.86687	77	26	7.7	1.1	None
25	AKW 25	Akwa-Ibom	Ibiono Ibom	Ikot Ada-Idem	N05.07328	007.86118	76	21	9.5	1.3	None
26	AKW 26	Akwa-Ibom	Ibiono Ibom	Ikot Ada-Idem	N05.07317	007.86099	73	22	13.6	1.4	None
27	AKW 27	Akwa-Ibom	Ibiono Ibom	Ikot Amang	N05.06003	007.86919	80	21	9.5	2.5	None
28	AKW 28	Akwa-Ibom	Etinan	Afaha Efiat Iman	N04.95609	007.84040	52	30	6.7	1.1	None
29	AKW 29	Akwa-Ibom	Etinan	Afaha Efiat Iman	N04.95522	007.84001	47	22	9.1	1.1	None
30	AKW 30	Akwa-Ibom	Ibiono Ibom	Ikot Osukpong	N05.05946	007.86677	77	20	10.0	1.2	None
31	AKW 31	Akwa-Ibom	Ikot Ekpene	Ibiakpan	N05.15970	007.73616	93	23	8.7	1.1	None
32	AKW 32	Akwa-Ibom	Ikot Ekpene	Ibiakpan	N05.15553	007.73702	86	20	10.0	1.5	None
33	AKW 33	Akwa-Ibom	Ikot Ekpene	Atu Road	N05.17090	007.73008	87	21	9.5	1.1	None

34	AKW 34	Akwa-Ibom	Ikot Ekpene	Nton Osung	N05.17288	007.7231	74	25	8.0	1.1	None
35	AKW 35	Akwa-Ibom	Ikot Ekpene	Ibiakpan	N05.15917	007.74069	94	30	6.7	1.1	None
36	CRS 1	Cross Rivers	Odukpani	New Netim	N05.14220	008.34619	50	30	26.7	1.7	None
37	CRS 2	Cross Rivers	Odukpani	New Netim	N05.14138	008.34566	17	21	9.5	1.4	None
38	CRS 3	Cross Rivers	Odukpani	New Netim	N05.14067	008.34714	25	30	6.7	1.2	None
39	CRS 4	Cross Rivers	Odukpani	Qua Town	N05.13394	008.34227	26	21	9.5	1.1	None
40	CRS 5	Cross Rivers	Odukpani	Qua Town	N05.10840	008.34300	66	22	9.1	1.3	None
41	CRS 6	Cross Rivers	Calabar Municipal	Old Airport	N05.97275	008.35045	65	25	8.0	1.2	None
42	CRS 7	Cross Rivers	Calabar Municipal	Old Airport	N05.97314	008.35014	60	26	7.7	1.2	None
43	CRS 8	Cross Rivers	Akamkpa	Union Bank Quarters	N05.31824	008.35124	101	21	9.5	1.1	None
44	CRS 9	Cross Rivers	Akamkpa	Police Barracks	N05.31858	008.35092	111	25	8.0	1.1	None
45	CRS 10	Cross Rivers	Akamkpa	Akamkpa	N05.31819	008.34958	109	20	10.0	1.3	None
46	CRS 11	Cross Rivers	Akamkpa	Akamkpa	N05.33311	008.33566	93	20	10.0	1.2	None
47	CRS 12	Cross Rivers	Akamkpa	Akamkpa	N05.32158	008.34383	99	21	14.3	1.4	None
48	CRS 13	Cross Rivers	Biase	Iwuru	N05.42734	008.16573	122	23	8.7	1.2	None
49	CRS 14	Cross Rivers	Biase	Ikot Ekpe	N05.43243	008.15551	108	21	9.5	1.2	None
50	CRS 15	Cross Rivers	Biase	Betem	N05.49251	008.15185	120	22	9.1	1.1	None
51	CRS 16	Cross	Biase	Adim	N05.73394	008.04055	16	20	10.0	1.3	None

		Rivers									
52	CRS 17	Cross Rivers	Biase	Adim	N05.73983	008.64202	34	20	10.0	1.2	None
53	CRS 18	Cross Rivers	Calabar Municipal	Mile 9	N05.07730	008.34770	85	21	9.5	1.2	None
54	CRS 19	Cross Rivers	Calabar Municipal	Mile 9	N05.07644	008.34727	78	20	10.0	1.2	None
55	CRS 20	Cross Rivers	Calabar Municipal	Mile 8	N05.07457	008.34874	66	25	8.0	1.2	None
56	CRS 21	Cross Rivers	Calabar South	Abitu	N04.92226	008.31807	13	23	8.7	1.1	None
57	CRS 22	Cross Rivers	Calabar South	Abitu	N04.92199	008.31761	11	24	8.3	1.2	None
58	CRS 23	Cross Rivers	Calabar South	Abitu	N04.92308	008.31797	16	20	10.0	1.2	None
59	CRS 24	Cross Rivers	Calabar South	New Airport Road	N04.93028	008.32383	32	21	9.5	1.1	None
60	CRS 25	Cross Rivers	Calabar South	Abitu	N04.92368	008.31784	12	20	10.0	1.2	None

Appendix 2. Survey for Maize and Sugarcane Viruses in Kaduna, Kano and Niger States, 6 – 15 August, 2014

S/No.	Field No.	State	LGA	Location	Longitude	Latitude	Altitude	No. of plants assessed	% symptomatic plants	Mean severity	Insects
1	NGR 1	Niger	Mokwa	Jebba	N09.16261	E004.81863	78	30	40.0	1.6	12
2	NGR 2	Niger	Mokwa	Tatabu	N09.24418	E004.92288	105	30	36.7	1.9	None
3	NGR 3	Niger	Mokwa	Mokwa	N09.30191	E005.04427	145	30	43.3	1.6	None
4	NGR 4	Niger	Mokwa	Mokwa	N09.32491	E005.16147	149	30	33.3	1.6	None
5	NGR 5	Niger	Lavun	Kutigi	N09.16586	E005.58678	204	30	43.3	1.7	None
6	NGR 6	Niger	Lavun	Kutigi	N09.16563	E005.58702	209	30	40.0	1.6	None
7	NGR 7	Niger	Lavun	Kutigi	N09.22058	E005.62185	212	30	40.0	1.6	None
8	NGR 8	Niger	Lavun	Panti	N09.22433	E005.67507	148	30	30.0	1.4	None
9	NGR 9	Niger	Gbako	Wuya	N09.14334	E005.84324	82	30	80.0	2.4	None
10	NGR 10	Niger	Gbako	Wuya	N09.14396	E005.84302	79	30	53.3	1.9	2
11	NGR 11	Niger	Gbako	Elagi	N09.11115	E005.94600	191	30	56.7	2.3	None
12	NGR 12	Niger	Bida	Bida	N09.08566	E006.01913	118	15	33.3	1.3	None
13	NGR 13	Niger	Bosso	Gidan Mangoro	N09.56648	E006.49119	226	23	30.4	1.6	None
14	NGR 14	Niger	Bosso	Dama	N09.55629	E006.42981	221	30	26.7	1.4	2
15	NGR 15	Niger	Bosso	Gidan Kwano	N09.53642	E006.46944	229	30	36.7	1.6	None
16	NGR 16	Niger	Bosso	Gidan Kwano	N09.50733	E006.45495	236	30	43.3	2.0	12
17	NGR 17	Niger	Minna	Minna	N09.60784	E006.57686	269	30	36.7	1.8	7
18	NGR 18	Niger	Minna	Minna	N09.62087	E006.58019	282	30	36.7	1.8	2
19	NGR19	Niger	Minna	Maitumbi	N09.63664	E006.59352	317	30	60.0	2.9	None

20	NGR 20	Niger	Minna	Sabon Gurusu	N09.63846	E006.63920	312	30	46.7	2.2	None
21	NGR 21	Niger	Shiroro	Gunu	N09.68898	E006.72407	373	28	25.0	1.6	None
22	NGR 22	Niger	Shiroro	Kurmi Shayi	N09.68176	E00.76600	388	30	30.0	1.7	None
23	NGR 23	Niger	Shiroro	Mutum Daya	N09.69535	E006.78555	370	24	25.0	1.5	None
24	NGR 24	Niger	Shiroro	Kwalima	N09.69514	E006.82003	407	30	33.3	1.9	None
25	KDS 25	Kaduna	Kachia	Angwan Gajere	N09.91580	E007.30728	587	30	30.0	1.6	None
26	KDS 26	Kaduna	Kachia	Doka	N09.91504	E007.31074	580	30	30.0	1.8	None
27	KDS 27	Kaduna	Kachia	Sabon Gari Doka	N09.90775	E007.33604	571	24	33.3	2.0	None
28	KDS 28	Kaduna	Igabi	Jamare	N0109.74012	E007.51274	662	30	40.0	2.1	4
29	KDS 29	Kaduna	Igabi	Jamare	N10.74037	E007.51378	661	30	40.0	1.9	2
30	KDS 30	Kaduna	Igabi	Birnin Yero	N10.75476	E007.51972	655	30	36.7	2.0	8
31	KDS 31	Kaduna	Igabi	Angwan Bete	N10.81427	E007.56090	654	30	40.0	1.9	None
32	KDS 32	Kaduna	Zaria	Tariyan Sarki	N11.01663	E007.67307	646	30	40.0	2.0	None
33	KDS 33	Kaduna	Zaria	Gwargwaje	N11.04122	E007.67946	644	30	30.0	1.9	None
34	KDS 34	Kaduna	Zaria	Gwargwaje	N11.06116	E007.68305	653	30	60.0	2.6	None
35	KDS 35	Kduna	Sabon Gari	Makera	N11.11935	E007.69853	639	30	36.7	1.6	None
36	KDS 36	Kaduna	Sabon Gari	Dogarawa	N11.13719	E007.71432	652	25	36.0	2.0	7
37	KDS	Kaduna	Sabon Gari	Dogarawa	N11.14025	E007.72462	650	30	33.3	1.8	None

	37										
38	KDS 38	Kaduna	Giwa	Kona Agishi	N11.22521	E007.52311	699	30	40.0	1.9	None
39	KDS 39	Kaduna	Giwa	Kona Agishi	N11.22773	E007.51744	698	20	50.0	2.1	5
40	KDS 40	Kaduna	Giwa	Tashan Tomo	N11.23348	E007.50719	704	30	36.7	1.7	None
41	KDS 41	Kaduna	Kudan	Tashan Taba	N11.23644	E007.80200	683	30	30.0	1.5	None
42	KDS 42	Kaduna	Kudan	Hawan Maimashi	N11.24028	E007.81430	680	30	30.0	1.7	5
43	KDS 43	Kaduna	Kudan	Maraban Kaura	N11.28156	E007.85665	669	30	33.3	1.6	None
44	KDS 44	Kaduna	Makarfi	Noma	N11.31942	E007.89148	676	30	30.0	1.7	None
45	KDS 45	Kaduna	Makarfi	Tashan Yari	N11.33275	E007.89989	679	30	40.0	1.8	None
46	KNS 46	Kano	Gwale	Kona Dangora	N11.45090	E008.18441	614	30	30.0	1.7	None
47	KNS 47	Kano	Gwale	Tarau	N11.48855	E008.21839	589	30	36.7	1.7	None
48	KNS 48	Kano	Bebeji	Gwarmai	N11.53199	E008.25272	569	30	46.7	1.8	None
49	KNS 49	Kano	Bebeji	Ranka	N11.56030	E008.31953	524	30	50.0	2.0	None
50	KNS 50	Kano	Bebeji	Ranka	N11.55796	E008.32098	527	30	46.7	1.8	None
51	KNS 51	Kano	Bebeji	Ranka	N11.56576	E008.32094	525	30	36.7	1.7	None
52	KNS 52	Kano	Garun Mallam	Chiromawa	N11.62957	E008.39968	507	30	40.0	1.7	None
53	KNS 53	Kano	Garun Mallam	Chiromawa	N11.63112	E008.40149	504	30	46.7	1.7	None
54	KNS 54	Kano	Garun Mallam	Chiromawa	N11.63345	E008.40527	504	25	36.0	1.8	None

55	KNS 55	Kano	Ungogo	Umurawa	N11.91630	E008.53038	453	30	43.3	1.6	3
56	KNS 56	Kanp	Ungogo	Umurawa	N11.91505	E008.52819	456	30	36.7	1.5	None
57	KNS 57	Kano	Ungogo	Umurawa	N11.91392	E008.52288	460	28	35.7	1.7	None
58	KNS 58	Kano	Kumbotso	Challawa	N11.91273	E008.42054	460	30	33.3	1.6	None
59	KNS 59	Kano	Kumbotso	Challawa	N11.91113	E008.41826	444	30	36.7	1.6	None
60	KNS 60	Kano	Kumbotso	Challawa	N11.90741	E008.41513	450	30	40.0	1.6	None
61	KNS 61	Kano	Madobi	Kebe	N11.88975	E008.39102	455	27	33.3	1.7	None
62	KNS 62	Kano	Madobi	Kebe	N11.88972	E008.39110	454	30	36.7	1.6	None
63	KNS 63	Kano	Madobi	Kebe	N11.88692	E008.38712	459	30	30.0	1.5	None
64	KNS 64	Kano	Kiru	Dashi	N11.72259	E008.23444	512	30	43.3	1.8	None
65	KNS 65	Kano	Kiru	Dashi	N11.72100	E008.23097	521	30	46.7	1.8	None
66	KDS 66	Kaduna	Kagarko	Jere	N09.56374	E007.43059	562	30	33.3	1.8	None
67	KDS 67	Kaduna	Kagarko	Jere	N09.56024	E007.45508	571	30	30.0	1.7	None
68	KDS 68	Kaduna	Kagarko	Jere	N09.55339	E007.47390	574	30	26.7	1.6	None
69	NGR 69	Niger	Tafa	Sabon Wuse	N09.30375	E007.23281	509	30	30.0	1.6	None
70	NGR 70	Niger	Tafa	Sabon Wuse	N09.29663	E007.22683	531	30	23.3	1.5	None
71	NGR 71	Niger	Gurara	Diko	N09.27370	E007.21159	528	30	30.0	1.8	None
72	NGR	Niger	Gurara	Diko	N09.27295	E007.19806	510	30	26.7	1.5	None

	72										
73	NGR 73	Niger	Paikoro	Koropa	N09.52375	E007.58264	222	30	33.3	1.7	None
74	NGR 74	Niger	Paikoro	Pogo	N09.50686	E006.60406	325	27	37.0	1.9	None
75	NGR 75	Niger	Paikoro	Konayi	N09.47455	E006.63463	287	30	40.0	1.8	None
76	NGR 76	Niger	Paikoro	Kompani Dorowa	N09.40983	E006.70532	374	30	33.3	1.6	None

Appendix 3. Survey for Maize and Sugarcane viruses in Niger State, 26 Sept. – 1 October, 2014

S/No.	Field No.	State	LGA	Location	Longitude	Latitude	Altitude	No of plants assessed	% symptomatic plants	Mean severity	Insects
1	NGR 1	Niger	Bosso	Kodo	N09.69376	E006.23638	214	30	46.7	0.9	None
2	NGR 2	Niger	Wushishi	Haliko	N09.73328	E006.19917	183	30	40.0	1.1	None
3	NGR 3	Niger	Wushishi	Zungeru	N09.80288	E006.16043	164	30	40.0	1.2	None
4	NGR 4	Niger	Wushishi	Kona Barau	N09.86297	E006.12550	195	30	33.3	1.1	None
5	NGR 5	Niger	Rafi	Garin Gabas	N09.90374	E006.12026	246	30	26.7	0.9	None
6	NGR 6	Niger	Rafi	Yakila	N09.94124	E006.13797	239	30	26.7	1.3	None
7	NGR 7	Niger	Rafi	Gangara Katako	N09.97484	E006.15386	254	30	26.7	1.2	None
8	NGR 8	Niger	Bosso	Gusasi	N09.63773	E006.38960	281	30	30.0	1.1	5
9	NGR 9	Niger	Bosso	Popoi	N09.62937	E006.35825	240	30	30.0	1.3	None
10	NGR 10	Niger	Mariga	Hayi Dan Barde	N10.12856	E006.05322	233	30	33.3	1.2	None
11	NGR 11	Niger	Mariga	Anguwan Bala Baba	N10.13898	E006.00812	242	30	40.0	1.3	None
12	NGR 12	Niger	Mariga	Tasha Dan Danja	N10.16341	E005.94681	286	30	36.7	1.2	None
13	NGR 13	Niger	Kontagora	Farin Shiage	N10.40027	E005.54145	331	30	36.7	1.2	None
14	NGR 14	Niger	Kontagora	Mararaba	N10.38393	E005.43968	372	30	36.7	1.2	None
15	NGR 15	Niger	Kontagora	Kontagora	N10.36047	E005.42503	377	30	36.7	1.2	None
16	NGR 16	Niger	Gurara	Gwacipe	N09.26333	E007.07361	277	30	36.7	1.2	None
17	NGR 17	Niger	Suleja	Maje	N09.24536	E007.15923	525	30	33.3	1.3	None
18	NGR 18	Niger	Suleja	Kuchiko	N09.27213	E007.18630	519	30	40.0	1.2	None
19	NGR19	Niger	Suleja	Maje	N09.25365	E007.16368	492	23	34.8	1.4	None
20	NGR 20	Niger	Gurara	Wagu Sarki	N09.25222	E007.03772	276	24	37.5	1.2	None
21	NGR 21	Niger	Gurara	Miemi	N09.25569	E006.94912	257	30	40.0	1.2	None
22	NGR 22	Niger	Lapai	Lapai	N09.05349	E006.60801	224	30	33.3	1.3	None
23	NGR 23	Niger	Lapai	Lapai	N09.04531	E006.54760	177	30	43.3	1.3	None

24	NGR 24	Niger	Lapai	Nami	N09.03798	E006.48019	176	30	40.0	1.3	None
25	NGR 25	Niger	Agaie	Ipagwi	N09.02660	E006.38580	136	30	36.7	1.2	None
26	NGR 26	Niger	Agaie	Agaie	N09.02256	E006.35355	126	30	33.3	1.2	None
27	NGR 27	Niger	Agaie	Agaie	N09.01483	E006.30735	98	26	34.6	1.3	None
28	NGR 28	Niger	Bida	Bida	N09.12513	E006.06737	120	30	40.0	1.3	None
29	NGR 29	Niger	Bida	Egagi	N09.19434	E006.11450	103	30	33.3	1.2	None
30	NGR 30	Niger	Bida	Emi Nda Wuya	N09.22219	E006.13599	107	30	33.3	1.3	None
31	NGR 31	Niger	Munya	Jayi	N09.71807	E006.94739	428	30	36.7	1.2	None
32	NGR 32	Niger	Munya	Chigbani	N09.79730	E007.03274	425	30	26.7	1.3	None
33	NGR 33	Niger	Munya	Mangurata	N09.86813	E007.08428	484	30	30.0	1.2	None

Appendix 4. Survey for Maize and Sugarcane viruses in Ogun, Osun and Oyo States, 3 – 16 October, 2014

S/No.	Field No.	State	LGA	Location	Longitude	Latitude	Altitude	No. of plants assessed	% symptomatic plants	Mean severity	Insect
1	OY 1	Oyo	Oyo West	Ayetoro	N07.85660	E003.90152	297	26	7.7	1.2	None
2	OY 2	Oyo	Atiba	Jawaya	N07.92116	E004.01258	331	26	7.7	1.2	None
3	OY 3	Oyo	Atiba	Idi Ori	N07.89395	E004.00704	326	27	7.4	1.2	None
4	OY 4	Oyo	Atiba	Oko Olosa	N07.86803	E003.97657	342	27	7.4	1.2	None
5	OY 5	Oyo	Oyo East	Abologo	N07.85741	E003.95609	285	26	7.7	1.2	None
6	OY 6	Oyo	Oyo West	Fashola	N07.84501	E003.94973	219	26	7.7	1.3	None
7	OY 7	Oyo	Oyo West	Eleja	N07.88344	E003.85524	241	26	7.7	1.2	None
8	OY 8	Oyo	Oyo West	Ojogboju	N07.85557	E003.89732	274	26	7.7	1.2	None
9	OY 9	Oyo	Ogo Oluwa	Sekona Area	N08.08067	E004.17993	329	26	7.7	1.2	None
10	OY 10	Oyo	Ogo Oluwa	Agric Settlement	N08.09558	E004.19597	346	27	11.1	1.2	None
11	OY 11	Oyo	Ogbomosho North	Onigbede	N08.18307	E004.21330	328	26	7.7	1.2	None
12	OY 12	Oyo	Ogbomosho North	Ikose Ogbomosho	N08.18943	E004.20921	324	25	12.0	1.3	None
13	OY 13	Oyo	Ogbomosho North	Iluju	N08.20267	E004.20023	328	27	7.4	1.2	None
14	OY 14	Oyo	Saki East	Saki Kehulere	N08.68064	E003.68733	390	27	7.4	1.2	None
15	OY 15	Oyo	Saki East	Seperi	N08.64233	E003.65232	343	30	6.7	1.2	None
16	OY 16	Oyo	Saki East	Oje Owode	N08.60550	E003.47408	443	25	8.0	1.2	None
17	OY 17	Oyo	Saki East	Araromi	N08.62688	E003.44324	496	27	7.4	1.3	None
18	OY 18	Oyo	Saki West	Aroje	N08.58871	E003.39956	398	27	7.4	1.3	None
19	OY 19	Oyo	Saki West	Sabe	N08.45505	E003.40806	331	25	8.0	1.2	None
20	OY 20	Oyo	Saki West	Owotoro	N08.38176	E003.38857	334	27	7.4	1.3	None
21	OY 21	Oyo	Saki West	Otiri	N08.07143	E003.53287	324	25	8.0	1.3	None
22	OY 22	Oyo	Kajola Okeho	Olele Area	N08.04130	E003.45513	310	25	8.0	1.3	None

23	OY 23	Oyo	Kajola Okeho	Oyalugbo	N08.04285	E003.41536	366	28	7.1	1.2	None
24	OY 24	Oyo	Kajola Okeho	Ilupeju	N08.04047	E003.37223	380	25	8.0	1.2	None
25	OY 25	Oyo	Ibarapa	Obasanjo Farm	N07.66600	E003.44458	184	26	7.7	1.3	None
26	OY 26	Oyo	Ibarapa	Surulere Lanlate	N07.61448	E003.44957	16	26	7.7	1.2	None
27	OY 27	Oyo	Ibarapa	Gasa Lanlate	N07.51381	E003.39223	151	26	7.7	1.2	None
28	OY 28	Oyo	Ibarapa East	Agric Eruwa	N07.51478	E003.38863	131	25	8.0	1.3	None
29	OY 29	Oyo	Ibarapa Setter	Igbole Ibarapa	N07.41894	E003.30870	178	29	6.9	1.2	None
30	OGS 30	Ogun	Abeokuta North	Oke Ata	N07.13817	E003.27872	81	27	7.4	1.2	None
31	OGS 31	Ogun	Abeokuta North	Mongoro	N07.14042	E003.26876	71	27	7.4	1.2	None
32	OGS 32	Ogun	Abeokuta North	Ibara Orile	N07.19330	E003.23941	106	28	7.1	1.2	None
33	OGS 33	Ogun	Abeokuta North	Aiyetoro	N07.28646	E003.08532	183	26	7.7	1.2	None
34	OGS 34	Ogun	Odeda	Elewe Eran	N07.17096	E003.41954	183	25	8.0	1.3	None
35	OGS 35	Ogun	Odeda	Idera	N07.19584	E003.41635	171	27	7.4	1.2	None
36	OGS 36	Ogun	Odeda	Araromi	N07.20335	E003.47011	166	27	7.4	1.2	None
37	OGS 37	Ogun	Odeda	Agbeju	N07.22738	E003.50313	164	26	7.7	1.3	None
38	OGS 38	Ogun	Owode	Sagamu	N06.80330	E003.88276	68	28	7.1	1.2	None
39	OGS 39	Ogun	Ikenne	Akindoyin	N06.86245	E003.70781	48	27	7.4	1.2	None
40	OGS 40	Ogun	Ikenne	Itta Ikenne	N06.83861	E003.71283	65	28	7.1	1.2	None
41	OGS 41	Ogun	Ikenne	Agric. Ikenne	N06.81499	E003.72445	41	28	7.1	1.2	None
42	OS 42	Osun	Ayedire	Ikoyi	N07.64956	E004.30581	269	27	7.4	1.3	None
43	OS 43	Osun	Ayedire	Olobedanu	N07.64893	E004.31161	279	30	6.7	1.2	None
44	OS 44	Osun	Ayedire	Igbo- Akan	N07.64883	E004.31655	276	27	7.4	1.3	None
45	OS 45	Osun	Iwo	Igbo Ile	N07.64559	E004.29162	304	27	11.1	1.4	None
46	OS 46	Osun	Iwo	Oke Osun	N07.64545	E004.28782	284	26	7.7	1.2	None

47	OS 47	Osun	Iwo	Oke Ewu	N07.63189	E004.26249	290	27	7.4	1.2	None
48	OS 48	Osun	Iwo	Isale Araromi	N07.62044	E004.24613	289	27	7.4	1.3	None
49	OS 49	Osun	Ayedade	Mojapa	N07.56320	E004.29687	275	28	7.1	1.2	None
50	OS 50	Osun	Ayedade	Sewe	N07.52877	E004.31520	255	27	7.4	1.3	None
51	OS 51	Osun	Ayedade	Ajakas	N07.48601	E004.34560	245	28	7.1	1.2	None
52	OS 52	Osun	Ayedade	Oke Elu	N07.49105	E004.35795	240	26	7.7	1.3	None
53	OS 53	Osun	Ayedade	Ogi	N07.59643	E004.42293	262	28	7.1	1.2	None
54	OS 54	Osun	Ede South	Okoda	N07.69889	E004.47674	338	28	7.1	1.3	None
55	OS 55	Osun	Ede South	Abepe	N07.70213	E004.50606	376	27	7.4	1.3	None
56	OS 56	Osun	Ede South	Ajirere Area	N07.71944	E004.49827	345	27	7.4	1.2	None
57	OS 57	Osun	Ede South	Ata Oja	N07.75105	E004.52119	339	27	7.4	1.2	None
58	OS 58	Osun	Egbedore	Ido	N07.99292	E004.49562	325	25	8.0	1.2	None
59	OS 59	Osun	Egbedore	Onibu Eja	N07.78728	E004.47150	306	26	11.5	1.3	None
60	OS 60	Osun	Egbedore	Efon	N07.77172	E004.44550	333	26	7.7	1.3	None
61	OS 61	Osun	Egbedore	Oke Gada	N07.76020	E004.44484	299	25	12.0	1.3	None
62	OS 62	Osun	Ede North	Iso Pako	N07.74990	E004.43897	279	26	7.7	1.3	None
63	OS 63	Osun	Ede North	Ago	N07.71547	E004.44430	328	25	8.0	1.3	None
64	OS 64	Osun	Ede North	Ona Nla	N07.69832	E004.45222	314	25	8.0	1.3	None
65	OS 65	Osun	Ede North	Irese	N07.64767	EOO4.45097	307	25	8.0	1.3	None
66	OS 66	Osun	Ile Ife North	Moro	N07.54819	E004.58431	273	26	3.8	1.2	None
67	OS 67	Osun	Ile Ife North	Elebun Abon	N07.55940	E004.59902	300	26	7.7	1.3	None
68	OS 68	Osun	Ile Ife North	Ayegbaju	N07.59067	E004.63712	364	25	8.0	1.2	None
69	OS 69	Osun	Ile Ife North	Osu	N07.57390	E004.61106	356	26	7.7	1.3	None
70	OS 70	Osun	Ilesha East	Asoro	N07.60997	E004.77847	411	26	7.7	1.3	None
71	OS 71	Osun	Ilwesha East	Ilaje Area	N07.58913	E004.74213	415	25	8.0	1.3	None
72	OS 72	Osun	Ilesha East	Ojogbo Omifunfun	N07.61766	E004.79542	428	26	7.7	1.3	None

73	OS 73	Osun	Ilesha East	Erinmo Ilosa	N07.58031	E004.86716	387	27	7.4	1.3	None
74	OS 74	Osun	Irewole	Wasimi	N07.43922	E004.26638	205	27	7.4	1.2	None
75	OS 75	Osun	Irewole	Onireke	N07.40615	E004.23598	213	26	7.7	1.3	None
76	OS 76	Osun	Irewole	Ayegbaju	N07.38689	E004.18396	201	25	8.0	1.3	None
77	OS 77	Osun	Irewole	Unity	N07.38873	E004.21611	276	25	8.0	1.3	None
78	OS 78	Osun	Irewole	Balogun	N07.42263	E004.25628	233	30	6.7	1.2	None
79	OS 79	Osun	Isokan	Iroko Area	N07.47818	E004.33613	164	26	7.7	1.3	None
80	OS 80	Osun	Isokan	Apomu	N07.49855	E004.36452	249	25	8.0	1.3	None
81	OS 81	Osun	Isokan	Ikoyi	N07.53877	E004.39579	242	26	7.7	1.3	None
82	OS 82	Osun	Isokan	Akere	N07.59633	E004.42287	263	26	7.7	1.3	None

Appendix 5. Survey for Maize and Sugarcane viruses in Kwara, Niger and Ogun States, 6 – 19 November, 2014

S/No.	Field No.	State	LGA	Location	Longitude	Latitude	Altitude	No. of plants assessed	% symptomatic plants	Mean severity	Insect
1	NGS 1	NIGER	MOKWA	YANUA	N07.55963	E004.42291	181	30	43.3	1.2	None
2	NGS 2	NIGER	MOKWA	RANGA	N09.21057	E005.03668	89	30	50.0	1.4	None
3	NGS 3	NIGER	MOKWA	RANGA	N09.24990	E005.64947	135	30	43.3	1.3	None
4	NGS 4	NIGER	MOKWA	KIRANA	N09.20054	E004.86797	109	30	43.3	1.2	None
5	NGS 5	NIGER	MOKWA	JEBBA	N09.19055	E004.85686	117	30	43.3	1.2	None
6	NGS 6	NIGER	MOKWA	KAPSUN	N09.17346	E004.83707	92	30	46.7	1.3	None
7	NGS 7	NIGER	EDATI	EZHI	N09.34282	E005.21953	154	30	40.0	1.2	None
8	NGS 8	NIGER	LAVUN	TURU	N09.14095	E005.86232	92	30	46.7	1.3	None
9	NGS 9	NIGER	LAVUN	ENAGI	N09.14086	E005.86219	85	30	43.3	1.2	None
10	NGS 10	NIGER	LAVUN	BATATI	N09.14202	E005.84492	76	30	43.3	1.2	None
11	NGS 11	NIGER	LAVUN	WAYADI	N09.14089	E005.76219	92	30	40.0	1.1	None
12	NGS 12	NIGER	LAVUN	WUYA	N09.14042	E005.87095	88	30	43.3	1.1	None
13	NGS 13	NIGER	GBAKO	WUYA	N09.13018	E005.89879	159	30	43.3	1.1	None
14	NGS 14	NIGER	GBAKO	TARA	N09.09070	E005.94647	161	30	43.3	1.3	None
15	NGS 15	NIGER	GBAKO	TABA	N09.09456	E006.00167	166	30	43.3	1.2	None
16	NGS 16	NIGER	GBAKO	WUYADI	N09.09675	E006.01114	152	30	43.3	1.2	None
17	NGS 17	NIGER	BIDA	YAWA	N09.13612	E005.86218	86	30	43.3	1.1	None
18	NGS 18	NIGER	BIDA	OGURU	N09.14100	E005.86236	79	30	43.3	1.2	None
19	NGS 19	NIGER	BIDA	BURUYA	N09.14473	E005.85841	84	30	40.0	1.1	None
20	NGS 20	NIGER	BIDA	BIDA	N09.14099	E005.86363	91	30	40.0	1.1	None
21	NGS 21	NIGER	BIDA	BRAMA	N09.15775	E005.86237	94	30	36.7	1.0	None
22	NGS 22	NIGER	BIDA	SOKORO	N09.17826	E005.86641	188	30	43.3	1.2	None
23	NGS 23	NIGER	BIDA	BRANGI	N09.47047	E005.86469	84	30	40.0	1.1	None
24	NGS 24	NIGER	KATCHA	BADEGGI	N09.15603	E005.86185	90	30	36.7	1.0	None
25	NGS 25	NIGER	KATCHA	GBAKI	N09.14182	E005.85012	76	30	43.3	1.1	None
26	NGS 26	NIGER	KATCHA	YAKO	N09.14287	E005.84299	75	30	36.7	1.0	None

27	NGS 27	NIGER	KATCHA	GBADIYA	N09.14256	E005.84834	72	30	43.3	1.1	None
28	NGS 28	NIGER	KATCHA	SAKOTU	N09.12751	E005.92273	141	30	40.0	1.1	None
29	NGS 29	NIGER	KATCHA	EDOZHIGI	N09.10341	E005.96040	128	30	40.0	1.1	None
30	NGS 30	NIGER	KATCHA	DIGI	N09.13559	E005.88534	123	30	46.7	1.3	None
31	NGS 31	NIGER	KATCHA	JIWO	N09.08760	E006.02703	120	30	36.7	1.0	None
32	NGS 32	NIGER	KATCHA	ZUNGERU	N09.07773	E006.04810	134	30	40.0	1.0	None
33	NGS 33	NIGER	LAPAI	LAPAI	N09.07681	E006.10902	81	30	36.7	1.0	None
34	NGS 34	NIGER	KATCHA	BADEGGI	N09.07163	E006.10936	76	30	33.3	0.9	None
35	NGS 35	NIGER	KATCHA	MAGIGARI	N09.07029	E006.10873	86	30	33.3	27	None
36	NGS 36	NIGER	KATCHA	KUTIGERI	N09.03987	E006.26519	82	30	40.0	1.0	None
37	KWA 37	KWARA	MORO	SURULERE	N09.11296	E004.82254	125	30	40.0	1.1	None
38	KWA 38	KWARA	MORO	ILUPERI	N09.04227	E004.80843	169	30	36.7	1.0	None
39	KWA 39	KWARA	MORO	ILE PUPA	N09.06290	E004.81245	152	30	40.0	1.1	None
40	KWA 40	KWARA	MORO	BODE SA'ADU	N08.99004	E004.80481	177	30	40.0	1.1	None
41	KWA 41	KWARA	MORO	GBAKO	N08.93779	E004.78617	144	30	40.0	1.1	None
42	KWA 42	KWARA	KUFU ILORIN SOUTH	GENERAL	N08.69678	E004.61228	354	30	36.7	0.9	None
43	KWA 43	KWARA	KUFU ILORIN SOUTH	OLORO	N08.68700	E004.60701	349	30	40.0	1.0	None
44	KWA 44	KWARA	KUFU ILORIN SOUTH	KAMBI	N08.63879	E004.56916	265	30	40.0	1.1	None
45	KWA 45	KWARA	KUFU ILORIN SOUTH	MALETE	N08.61763	E004.55060	281	30	40.0	1.1	None
46	KWA 46	KWARA	KUFU ILORIN SOUTH	OKO OLOWO	N08.54257	E004.49782	324	30	40.0	1.0	None
47	KWA 47	KWARA	ILORIN WEST	OLOSE	N08.51395	E004.51096	314	30	36.7	1.0	None
48	KWA 48	KWARA	ILORIN WEST	ALORE	N08.50972	E004.51827	301	30	36.7	0.9	None
49	KWA 49	KWARA	ILORIN WEST	OMODA	N08.50418	E004.53522	323	30	36.7	1.0	None
50	KWA 50	KWARA	ILORIN WEST	KURU FARM	N08.49790	E004.54685	316	30	36.7	1.0	None
51	KWA 52	KWARA	ILORIN EAST	OSERE	N08.59084	E004.71148	364	30	40.0	1.1	None
52	KWA 53	KWARA	ILORIN EAST	OKE OYI	N08.58065	E004.71256	382	30	40.0	1.1	None

53	KWA 54	KWARA	ILORIN EAST	OLOSA	N08.60107	E004.74390	328	30	36.7	1.0	None
54	KWA 55	KWARA	ILORIN EAST	OOLORU	N08.58050	E004.71544	379	30	40.0	1.0	None
55	KWA 56	KWARA	ILORIN EAST	BADI	N08.61628	E004.78178	305	30	43.3	1.2	None
56	KWA 57	KWARA	ILORIN EAST	JEBBA ROAD	N08.60124	E004.70734	368	30	40.0	1.0	None
57	KWA 58	KWARA	ASA	OKIKI	N08.45968	E004.54217	121	30	36.7	0.9	None
58	KWA 59	KWARA	ASA	EYEPERIMI	N08.26165	F004.31372	388	30	36.7	1.0	None
59	KWA 60	KWARA	ASA	OKE SANA	N08.26852	E004.31752	410	30	33.3	0.9	None
60	KWA 61	KWARA	ASA	GAMBARI	N08.29639	E004.34482	405	30	36.7	1.0	None
61	KWA 62	KWARA	ASA	GBEDE	N08.31618	E004.39136	372	30	40.0	1.1	None
62	KWA 63	KWARA	ASA	EGBA	N08.31863	E004.39492	360	30	36.7	1.1	None
63	KWA 64	KWARA	IREPODUN	OTTE BUDO	N08.29674	E004.34540	400	30	36.7	1.0	None
64	KWA 65	KWARA	IREPODUN	AYOKUNFU	N08.23896	E004.30114	385	30	36.7	1.0	None
65	KWA 66	KWARA	IREPODUN	OKE FARI	N08.76362	E004.25903	346	30	36.7	0.9	None
66	KWA 67	KWARA	IREPODUN	GBAGBA ASA	N08.14529	E004.23501 1	356	30	40.0	1.0	None
67	KWA 68	KWARA	IREPODUN	ORIRE	N08.13613	E004.23169	359	30	36.7	0.9	None
68	KWA 69	KWARA	IREPODUN	GABARI	N08.20222	E004.20069	318	30	40.0	1.1	None
69	KWA 70	KWARA	EWEKORO	PANPA	N06.88542	E003.19073	44	30	40.0	1.0	None
70	KWA 71	KWARA	EWEKORO	ILARO	N06.88576	E003.18951	38	30	43.3	1.2	None
71	KWA 72	KWARA	EWEKORO	ILARO	N06.88843	E00318059	39	30	43.3	1.1	None
72	KWA 73	KWARA	EWEKORO	PANTO	N06.88939	E003.17719	34	30	40.0	1.2	None
73	KWA 74	KWARA	EWEKORO	YANA AYETORO	N06.88813	E003.19599	29	30	43.3	1.1	None
74	OGS 75	OGUN	EGBEDA	ELEWE ERAN	N06.92197	E003.21623	17	30	46.7	1.2	None
75	OGS 76	OGUN	EGBEDA	OKE OKO	N06.96072	E003.22294	62	30	40.0	1.0	None
76	OGS 77	OGUN	EGBEDA	ILUPEJU	N06.93517	E003.22190	27	30	43.3	1.1	None
77	OGS 78	OGUN	EGBEDA	KAMOKUN	N06.99622	E003.22623	65	30	40.0	1.0	None
78	OGS 79	OGUN	EGBEDA	MOFOLURIN	N07.03621	E003.23884	56	30	43.3	1.2	None
79	OGS 80	OGUN	IJEBU EAST	LAILAI	N07.08678	E003.29380	59	30	40.0	1.1	None
80	OGS 81	OGUN	IJEBU EAST	IKENNE	N07.11548	E003.29765	41	30	40.0	1.0	None
81	OGS 82	OGUN	IJEBU EAST	OBASANJO	N07.14702	E003.32691	29	30	43.3	1.1	None

				FARM							
82	OGS 83	OGUN	IJEBU EAST	REMO AREA	N07.15643	E003.33426	61	30	40.0	1.1	None
83	OGS 84	OGUN	IJEBU NORTH	SHAGAMU	N07.15580	E003.33363	54	30	43.3	1.1	None
84	OGS 85	OGUN	IJEBU NORTH	TOTORO	N06.88858	E003.18012	42	30	40.0	1.0	None
85	OGS 86	OGUN	IJEBU NORTH	MANTORU	N06.89391	E003.19981	26	30	40.0	1.1	None
86	OGS 87	OGUN	IJEBU NORTH	AWOSANJO	N06.93293	E003.21971	30	30	40.0	1.0	None
87	OGS 88	OGUN	IFO	IBARA	N06.97123	E003.22186	68	30	40.0	0.9	None
88	OGS 89	OGUN	IFO	AWOSANYA	N07.01020	E003.22809	91	30	36.7	0.9	None
89	OGS 90	OGUN	IFO	OBADA	N07.15491	E003.32495	32	30	36.7	1.0	None
90	OGS 91	OGUN	IFO	AGO IKA	N07.16917	E003.35888	106	30	40.0	1.0	None
91	OGS 92	OGUN	SHAGAMU	OBADA	N06.88859	E003.18008	43	30	40.0	1.0	None
92	OGS 93	OGUN	SHAGAMU	SOWUNMI	N06.86861	E003.27402	23	30	40.0	1.1	None
93	OGS 94	OGUN	SHAGAMU	MOSE-BALOGUN	N06.86618	E003.23069	31	30	36.7	0.8	None

Appendix 6. Data Collection Sheet

Virology & Molecular Diagnostics Unit, IITA, Ibadan

Maize Viruses Survey – 2014			
Sheet #		Field size	
Date/Time		Age (wks)	
Location name		Varieties	
District/LGA			
State		Intercrops	
Agro-ecology			
Latitude		Crops in neighbouring fields	
Longitude			
Altitude (m)		Researcher (farmer)	
Summary	Percent infection:	Average severity:	Severity range:

Plant (#)	Symptoms	Severity score	Insects (thrips/rootworms/aphids/whiteflies/ Beetles/leafhoppers)			Details of sampled plant				
			P#	Adults	Nymphs	P#	Photo ID	Symptoms	Sev. score	Variety
1			1			1				
2			2			2				
3			3			3				
4			4			4				
5			5			5				
6										
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Abbreviations for symptom description

Prefix: m – mild; o – moderate; s – severe

Suffix: m – mosaic; mo – mottling; puc – puckering; st – stunting; d – deformation; de – death

1. No visible symptoms; plants apparently healthy
2. Mild mosaic/mild mottling on few leaves/branches of a plant (symptoms on 25% of the plant)
3. Mosaic/puckering/mottling/necrosis/vein clearing symptoms cover 50% of the plant
4. Severe mosaic/puckering/mottling/yellowing/necrosis (symptoms on entire plant) but no stunting of deformation
5. Severe mosaic/mottling/yellowing/necrosis and severe stunting (entire plant) deformation and death of the infected plants