Tackling the MLN Challenge through R4D – Initiatives by CIMMYT and Partners

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Emergence of MLN in eastern Africa

- **September 2011:** Disease first reported in the lower parts of Longisa division of Bomet District of Kenya.
- **February 2012**: Noticed in Bomet Central division, spreading into neighboring Chepalungu, Narok North, Narok South and Naivasha Districts of Kenya.
- **April 2012**: Disease further spread to Sotik,, Koinon, Transmara, Rumuruti, Kisii, Bureti, Kericho, Mathira East, Imenti South and Embu Districts of Kenya
- **In Tanzania**: Lake zone (Mwanza and Musoma), Manyara, Arusha and Moshi

Disease Symptoms

Disease Symptoms

Poor seed set and shrivelled ears

Shortened Internodes

Early leaf necrosis

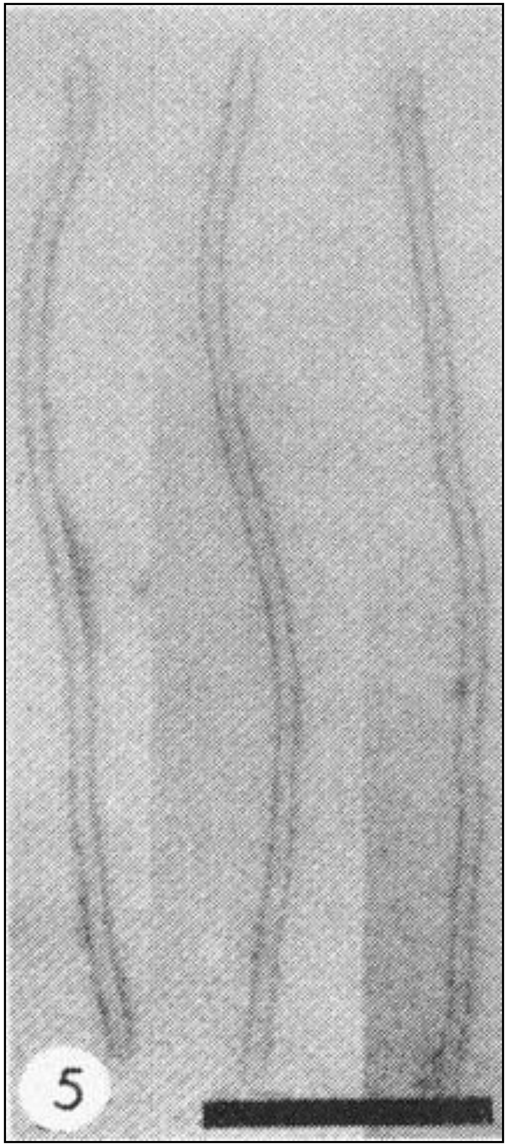
Pathogen Diagnosis

- Collaboration between KARI, CIMMYT and USDA/OSU (Wangai et al. 2012)

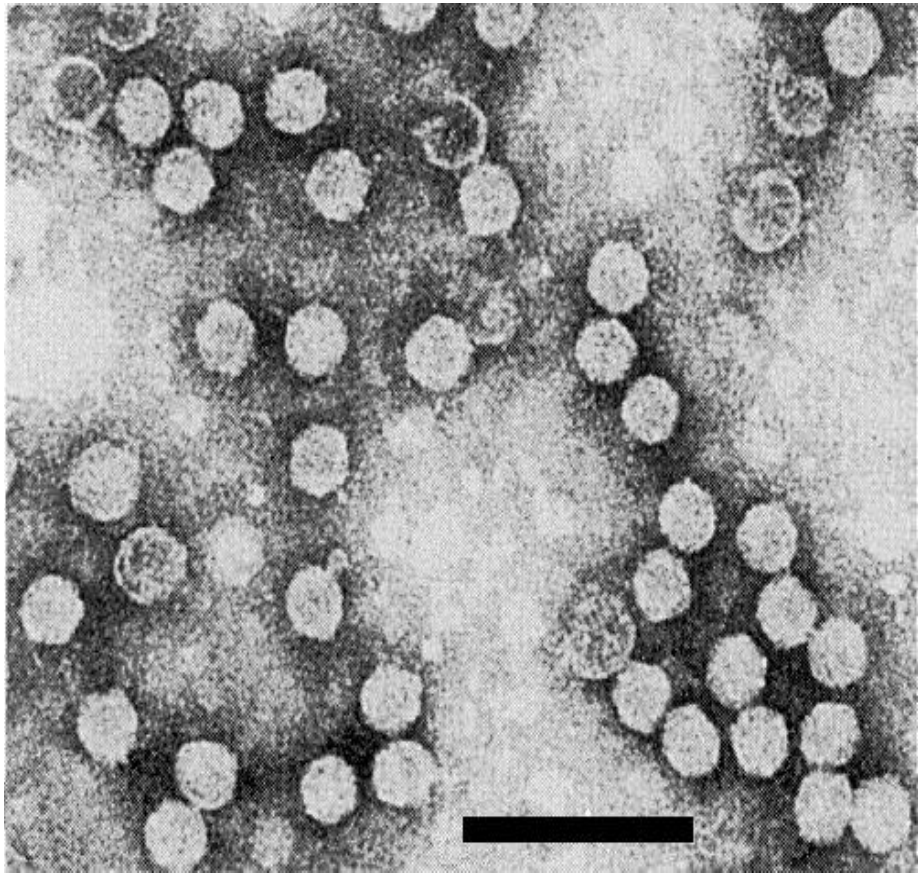
- First report of MCMV in Kenya.

- MLN is a viral disease caused by combined infection of maize with Maize Chlorotic Mottle Virus (MCMV) and any of the Potyviruses infecting cereals (e.g., SCMV, MDMV or WSMV).

Sugarcane mosaic virus (SCMV)



Maize chlorotic mottle virus (MCMV)



Global occurrence of MCMV/MLN

Country	MCMV / MLN	Year	Reference
Peru	MLN	1973	Castillo and Hebertt (1974)
USA	CLN	1976	Niblett and Cafflin (1976)
Argentina	CLN	1982	Teyssandier et al. (1982)
Mexico	MCMV/MLN	1987	Delgadillo and Gaytan (1987)
Thailand	MCMV	1983	Cited in Uyemoto (1983)
Brazil	MCMV	1983	Cited in Uyemoto (1983)
China	MLN	2011	Xie et al. (2011)
Kenya	MLN	2012	Wangai et al. (2012)
Tanzania	MLN	2012	CIMMYT Task Force Report to Ministry of Agriculture, Tanzania
Uganda	MLN	2012	Godfrey Asea's presentation in MLN Workshop (Nairobi; Feb 12-13, 2013)
Rwanda	MCMV	2013	Claver Ngabiyasonga's presentation during MLN Training Workshop (Nairobi; July 1, 2013)

MLN in a Hybrid Seed Production Field in Tanzania

Seed industry under stress in EA

- Seed demand has decreased in the MLN-affected region by several thousand tons.
- Demand has changed; sales have reduced.
- Lots of carry over seed.
- Import restrictions
- Seed treatment with systemic insecticides:
  - Increase in cost of seed
  - Product not available

Severe vulnerability of commercial varieties released in Kenya

Screening of **119** commercial maize varieties (both hybrids and OPVs) released in Kenya under MLN artificial inoculation trials in Naivasha and Narok in Kenya revealed **117** if these are highly vulnerable to MLN!

Source: STAK-KARI trials (2012-13)

Why is MLN devastating in EA?

- MCMV is new to the region + interaction with SCMV (new strains?) in the region
- Conducive environment for survival and spread of insect vectors
- Continuous maize cropping in certain regions – build-up of virus inoculum
- Widespread cultivation of susceptible germplasm that has never been screened for MCMV

MLN Facts and Actions

Maize lethal necrosis (MLN) disease in Kenya and Tanzania: Facts and actions

A serious new disease of maize appeared in the farmers' fields in eastern Africa in 2011. Called maize lethal necrosis (MLN; or corn lethal necrosis, CLN), it can devastate maize crops. The disease is difficult to control for two reasons:

1. **It is caused by a combination of two viruses that are difficult to differentiate individually based on visual symptoms.**
2. **The insects that transmit the disease-causing viruses may be carried by wind over long distances.**

National and global research and extension organizations, laboratories, and seed companies are working together to control the spread of the disease and to develop and deploy disease-resistant maize varieties for the farmers as soon as possible.

What causes MLN?

The disease was first identified in the USA in 1976 (Niblett and Claflin 1978). MLN 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). MCMV or SCMV typically produce milder symptoms when they infect maize alone; in combination, these two viruses rapidly produce a synergistic reaction that seriously damages or kills infected plants.

Where has MLN appeared?

Kenya: Initial reports of an unknown disease outbreak surfaced in September 2011 in the Bomet county in the South Rift Region; further reports appeared in early 2012 in Naivasha, Narok North, Narok South, Chepalungu, and Sotik, as well as parts of the Eastern Province (Embu and Meru) and the Central Province (Murang'a, Kirinyaga, and Nyeri). MLN has also been reported recently in Trans-Nzoia, Uasin Gishu, and Busia.

A scientific team from the Kenya Agricultural Research Institute (KARI) and the International Maize and Wheat Improvement Center (CIMMYT) sampled infected maize plants in Bomet and Naivasha in February-March 2012. The samples were tested by serology and molecular methods for the presence of MCMV and SCMV at USDA-ARS/Ohio State University (Peg Redinbaugh's Laboratory), Wooster, Ohio, USA, as well as at the Food and Environment Research Agency, Sand Hutton, York, using next-generation sequencing with results and clearly indicating the presence of MLN (Wangai et al. 2012, Adams et al. 2012).

Tanzania: In August 2012, reports of an unknown maize disease emerged from Mwanza, near Lake Victoria, and Arusha. CIMMYT was invited by the government of Tanzania to survey the affected regions and identify the disease. Infected plant samples from the Mwanza and Arusha regions were serologically positive for MCMV and SCMV, confirming the presence of MLN.

Is MLN a new disease?

Yes, although one of its component viruses, SCMV, was reported in Kenya many years ago (Louie 1980). MCMV is a new virus for Africa; it had not been reported previously in Kenya, but was first identified in Peru in 1973 (Castillo and Hebert 1974) and subsequently reported in the USA, parts of Latin America, and China (Niblett and Claflin 1978; Uyemoto 1983; Xie et al. 2011). Wangai et al. (2012) reported MCMV and MLN in Kenya for the first time.

What are the typical symptoms?

- Mild to severe mottling on the leaves, usually starting from the base of young leaves in the whorl and extending upwards toward the leaf tips.
- Stunting and premature aging of the plants.
- Dying (known as "necrosis") of the leaf margins that progresses to the mid-rib and eventually the entire leaf.
- Necrosis of young leaves in the whorl before expansion, leading to a symptom known as "dead heart" and eventually plant death.

How severe are farm-level crop losses?

Infection rates and damage can be very high, seriously affecting yields and sometimes causing complete loss of the crop (Wangai et al. 2012; Adams et al. 2012). Infected plants are frequently barren; ears formed may be small or deformed and set little or no seed.

KARI

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When and how are maize plants infected?

Maize plants are susceptible to MLN at all stages in their growth, from seedling to maturity. As with all viral diseases in plants, a carrier—known as a "vector"—transmits the MLN-causing viruses from plant to plant and field to field. MCMV is carried by thrips and beetles (Nault et al. 1978; Jiang et al. 1992) and SCMV by aphids (Brandes 1920; Pemberton and Charpentier 1969). Transmission of MCMV via seed from infected plants is normally very low (0.04%; Jensen et al. 1991).

How can MLN be controlled?

Based on CLN/MLN management experiences in the USA, rigorous disease management practices in seed production plots, including use of resistant varieties, controlling weeds/alternate hosts, keeping unnecessary machines/people out of the field, controlling insect-vectors using appropriate insecticide (at weekly intervals), and having adequate isolation from MLN-infected fields, can prevent the spread of the disease. Because individual plants with MCMV or SCMV alone show milder symptoms, seed production fields must be carefully inspected and plants that appear infected removed immediately.

How can farmers prevent MLN in their fields?

- MLN does not occur on crops other than maize; so avoid growing maize after maize. Diversify your farm enterprise by planting different crops each season.
- Do not plant a new maize crop near an infected field. Wind-blown insect vectors can transmit the disease from the infected field to the new crop.
- Plant maize at the onset of the main rainy season, rather than during the short rain season; this creates a break between maize crops and interrupts the disease cycle.
- Weed fields regularly to eliminate alternate hosts for insect vectors.
- Use maize varieties that are resistant to MLN.

What should farmers do if they find MLN in their fields?

- Immediately remove diseased plants from your fields. You can feed the leaves to livestock.
- Do not allow humans or animals to eat infected ears or grains, which may contain secondary fungal infections and harmful mycotoxins. Burn infected ears and grains.

Can MLN resistant maize varieties be developed soon?

Preliminary data from one season of screening under natural disease pressure of 43 pre-commercial maize hybrids and 7 commercial hybrids at Bomet, Chepkitwal and Naivasha (Table 1), and of 200 elite inbred lines at Naivasha (Table 2) suggest that MLN-resistant maize germplasm can be identified and developed quickly. KARI, CIMMYT, and other partners will reconfirm the potential resistance of pre-commercial hybrids and inbreds that showed the least susceptibility to MLN and work urgently to develop resistant varieties.

Are there potential sources of SCMV resistance?

Because MLN requires simultaneous infection by two viruses, resistance against any one of the causal viruses could significantly reduce crop damage. Results of a trial of elite CIMMYT inbred lines under artificial SCMV inoculation showed several highly-resistant lines (Table 3).

Table 1. MLN incidence on selected pre-commercial CIMMYT hybrids with least susceptibility under natural disease pressure (Kenya 2012 trials).

Entry	Naivasha			Bomet			Chepkitwal		
	DS	% DPLT	Rating	DS	% DPLT	Rating	DS	% DPLT	Rating
CKH10767	2.0	0	MR	2.6	26.2	MR	2.3	0	MR
CKH114272	2.0	8.9	MR	2.3	19.5	MR	2.1	15.2	MR
CKH101509	2.5	16.0	MR	1.9	13.3	MR	2.5	17.8	MR
Mean of three most susceptible commercial hybrids (checks)	2.9	44.5		3.4	34.7		2.8	23.4	
Min (across trial)	1.5	0		1.1	9.3		2.1	0.0	
Max (across trial)	4.0	42.8		4.2	67.1		3.9	53.5	
LSD (0.05)	1.2	19.1		1.2	11.8		0.62	10.8	

The trials were undertaken under natural disease (MLN) pressure at all the locations, using an alpha-lattice design with two replications per location, following standard agronomic management. They received no insecticide application.

DS: Disease Severity score (on 1-5 scale, with 1 = no symptoms; 5 = highly diseased) at different stages; %DPLT: % Dead Plants; MR: Moderately Resistant; MS: Moderately Susceptible; S: Susceptible.

MLN Regional Workshop and Field Day (Feb 12-14, 2013)

- 70 scientists, seed company breeders/managers, and representatives of Ministries of Agriculture and regulatory authorities in Kenya, Uganda and Tanzania
- Training on MLN disease diagnostics
- MLN field day showed responses of diverse maize germplasm to responses to MLN under high disease pressure
- KEPHIS representative announced the commitment to fast-track MLN resistant hybrid release.

Optimizing artificial inoculation protocols

SCMV amplification

MCMV+SCMV amplification

Inoculum preparation

MCMV amplification

Inoculum application using a mounted pressure sprayer in a trial in Narok (MLN Hot Spot) in Kenya

Technical support from USDA/OSU and KARI

Do we have elite maize germplam resistant to MLN?

Screening of inbred lines developed by CIMMYT, IITA and KARI, as well as CIMMYT pre-release hybrids against MLN during 2012-2013

CIMMYT-KARI team evaluated so far ~1000 maize genotypes in MLN trials:

- 335 elite inbred lines and 366 pre-commercial hybrids under artificial inoculation in Narok (Kenya)
- 350 elite inbred lines and 135 pre-commercial hybrids under natural disease pressure in Naivasha (Kenya)

10-15% of the evaluated maize germplam revealed resistance or moderate resistance against MLN!

Promising CIMMYT inbreds and pre-release hybrids against MLN identified

UPDATE: Promising CIMMYT maize inbreds and pre-commercial hybrids identified against maize lethal necrosis (MLN) in eastern Africa

The maize lethal necrosis (MLN) disease first appeared in Kenya's Rift Valley in 2011 and quickly spread to other parts of Kenya, as well as to Uganda and Tanzania. Caused by a synergistic interplay of maize chlorotic mottle virus (MCMV) and any of the cereal viruses in the family, Potyviridae, such as *Sugarcane mosaic virus* (SCMV), Maize dwarf mosaic virus (MDMV), or Wheat streak mosaic virus (WSMV), MLN can cause total crop loss if not controlled effectively.

A regional workshop on MLN and the control strategies was organized by CIMMYT and Kenya Agricultural Research Institute (KARI) during February 12-14, 2013 in Nairobi, which was attended by 70 scientists, seed company breeders and managers, and representatives of ministries of agriculture and regulatory authorities in Kenya, Uganda, Tanzania, and the USA. The Workshop led to identification of important action points steps for effectively controlling the disease.

CIMMYT scientists have been working closely with virology experts from USDA-ARS and KARI to develop suitable protocols for testing the responses of maize germplasm against MLN, and to identify promising inbred lines and hybrids with resistance to MLN. During the 2012-2013 crop season, the CIMMYT-KARI team undertook extensive screening of inbred lines, pre-commercial and commercial hybrids in Naivasha and Narok in Kenya, under high natural disease pressure and artificial inoculation, respectively.

A trial featuring 119 commercial maize varieties (released in Kenya) under artificial inoculation during 2012-2013 revealed that as many as 117 varieties were susceptible to MLN. Another set of trials including 335 elite inbred lines, 366 pre-commercial hybrids and 7 commercial hybrids (as checks) under MLN artificial inoculation in Narok, and another set of trials comprising 350 elite inbred lines and 135 pre-commercial hybrids under natural disease pressure in Naivasha, led to identification of some promising CIMMYT inbred lines as well as pre-commercial hybrids showing resistance or moderate resistance. These results offer considerable hope to combat, through breeding efforts, the deadly MLN disease that has severely affected maize harvests and discouraged farmers from growing maize in eastern Africa.

Notes on trial results

The details of the promising CIMMYT elite inbred lines and pre-commercial hybrids against MLN are presented in Tables 1 and 2, respectively. The results presented in Table 1 are based on evaluation of CIMMYT inbred lines in four independent trials, two under artificial inoculation (Narok) and two under natural disease pressure (Naivasha) during 2012-2013. In each trial, entries were replicated (minimum two), and MLN severity scores (on a 1-5 scale basis) were recorded three or more times during the crop cycle, from the vegetative to the reproductive stage. The highest average MLN severity score (max. MLN score), recorded at any stage during the trial, is presented as representative of a given entry.

The data must be critically assessed and cautiously used by stakeholders and partners. More weight should be given to data from artificially inoculated trials, since trials under natural disease pressure are more liable to 'disease escapes' and identification of false positives. Caution must be exercised when using specific lines identified as potentially resistant (R) or moderately resistant (MR), especially when classification is based on data from only one trial (even under artificial inoculation). Please note that in such cases, the responses of the lines need to be validated by CIMMYT through further trials.

CIMMYT is working closely with both public and private sector partners to significantly expand the MLN evaluation network capacity in eastern Africa, and will continue the intensive efforts to identify/develop and deliver new sources of resistance to MLN.

KARI

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Table 1. Responses of selected CIMMYT inbreds against MLN under artificial inoculation and/or natural disease pressure in Kenya (2012-2013)

Inbreds	Kernel Color	Heterotic Group	Maximum MLN Severity Score				Disease Response Rating
			AI		NDP		
			NRK-1	NRK-2	NVH-1	NVH-2	
CLRCY034	Y	B		1.5			R
DTPYC9-F46-1-2-1-2-B	Y	A		1.8			R
CKDHL0500	W	B	1.8				R
CKDHL0159	W	B	2.0				R
CKL05003 (CML543)	W	B	2.2	2.1	2.2	2.1	MR
La Posta Seq C7-F64-2-4-1-1-B-B-B-B-B	W	B	2.5	1.9	2.0	1.7	MR
CML144	W	A	2.5	2.5			MR
CL-02510	W	B		2.8	1.9	2.3	MR
CML312-SR	W	A	2.8		2.2	2.0	MR
ZM523A-16-2-1-1-B*5-B-B	W	A	2.8		2.1	2.4	MR
CML445	W	AB	2.5		2.9	2.9	MR
CLRCY039	Y	B		1.6		2.3	MR
CLYN261	Y	A		1.9		2.6	MR
CML247	W	A			2.8	2.0	MR
CML348	Y	B			1.6	2.5	MR
CML451	Y	B			2.5	2.5	MR
CLRCW97	W	A			2.3	2.0	MR
[CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-2-1-BB-B-B-B	W	B			2.0	2.1	MR
La Posta Seq C7-F32-2-1-1-1-B-B-B-B	W	B			1.7	2.5	MR

MLN Severity Scoring (1-5 Scale)
1 = No MLN symptoms
2 = Fine chlorotic streaks on lower leaves
3 = Chlorotic mottling throughout plant
4 = Excessive chlorotic mottling and dead heart
5 = Complete plant necrosis

Abbreviations
NRK-1: Narok Season 1; NRK-2: Narok Season 2; NRK-3: Narok Season 3

Disease Response Rating
R: Resistant (max. MLN severity score ≤2.0)
MR: Moderately resistant (max. MLN severity score ≥2.0 but ≤3.0

Table 2. Selected CIMMYT pre-release hybrids showing potential resistance or moderate resistance against MLN under artificial inoculation in Narok, Kenya (2012-2013).

Hybrid	Pedigree	NRK-1		NRK-2		NRK-3		Disease Response Rating
		Max. MLN Severity Score	Grain Yield (t/ha)	Max. MLN Severity Score	Grain Yield (t/ha)	Max. MLN Severity Score	Grain Yield (t/ha)	
CHMLND0093	CML442/CML312//CLWN232	2.0	6.78					R
CKIR11027	[(MBR C5 Bc F8-1-1-1-B-2-2-B)/CML204] S1-4-B-1-1-1-3// (CML312/CML442)	2.0	5.48					R
CKIR12032	CML440/CML445)//P590 C7 Blancos F156-1-2-1-B-B-B-B-B-B	2.0	5.34					R
CKIR12010	Under NPT in Kenya	2.0	4.09					R
CHMLND0168	CML312/CML395	2.5	5.37	2.8	6.59			MR
CHMLND0174	CML78/P300C5S1B-2-3-2-#-#-1-2-B-B-#	2.8	4.88	2.3	4.82	2.7	4.01	MR
CKIR12014	CML312/CML442//MBR E.T(W)C3 S5/SINTxMBR F15-2-1-2-B-B-B-B-B-B	2.1	7.43					MR
CKIR12037	(CML395/CML444)//P501c1#-500-2-1-2-2-2-4-1-B-B-3-Bx200-6 x GUAT 189-F1-B-#-B-1-2-B-B-B-B-B-B	2.2	6.99					MR
CKIR11010	[(MBR C5 Bc F8-1-1-1-B-2-2-B)/CML204] S1-4-B-1-1-1-1// (CML395/CML444)	2.3	7.11					MR
CKIR11025	[(MBR C5 Bc F8-1-1-1-B-2-2-B)/CML204] S1-4-B-1-1-1-1// (CML312/CML442)	2.3	6.49					MR
CKDHH0893	(CML539/CML442)//CK-DHL0295	2.3	5.16					MR
CHMLND0055	Under WEMA-Wide Trial	2.5	7.12					MR
CKIR12040	(CML78/P300C5S1B-2-3-2-#-#-1-2-B-B-#)//P501c1#-500-2-1-2-2-2-4-1-B-B-3-Bx200-6 x GUAT 189-F1-B-#-B-1-2-B-B-B-B-B-B	2.5	6.65					MR
CHMLN0178	CML144/CML159	2.5	5.67					MR
CKH10085	Under NPT In Kenya	2.7	6.75					MR
CHMLND0086	CML442/La Posta Seq C7-F64-2-6-2-2-B-B//CLWN201	2.8	7.52					MR
CHMLND0076	(CML78/P300C5S1B-2-3-2-#-#-1-2-B-B-#)//CKDHL0374	2.8	6.09					MR
CHMLN0149	CKDHL0228/CML442	2.8	5.15					MR

Abbreviations
Y: Yellow; W: White
AI: Artificial inoculation; NDP: Natural disease pressure
NRK-1: Narok Season 1; NRK-2: Narok Season 2
NVH-1: Naivasha Season 1; NVH-2: Naivasha Season 2

MLN Severity Scoring (1-5 Scale)
1 = No MLN symptoms
2 = Fine chlorotic streaks on lower leaves
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4 = Excessive chlorotic mottling and dead heart
5 = Complete plant necrosis

- Several more promising pre-release hybrids under validation trials in Narok this season.
- Seed requests for promising inbred lines and hybrids will be attended to in July-August 2013.

Ensuring a continuous flow of MLN resistant elite maize germplasm in SSA

- **Integrating MLN resistance** as an integral component of maize breeding strategy and product pipeline, across projects.
- Establishing a **centralized MLN screening facility** in KARI-Naivasha (under artificial inoculation) is in progress
- Opportunity for screening elite germplasm for CIMMYT, KARI as well as other public and private sector partners in eastern Africa.
- A **network of MLN testing sites** (under natural disease pressure) in eastern Africa to evaluate promising materials from artificial inoculation trials.

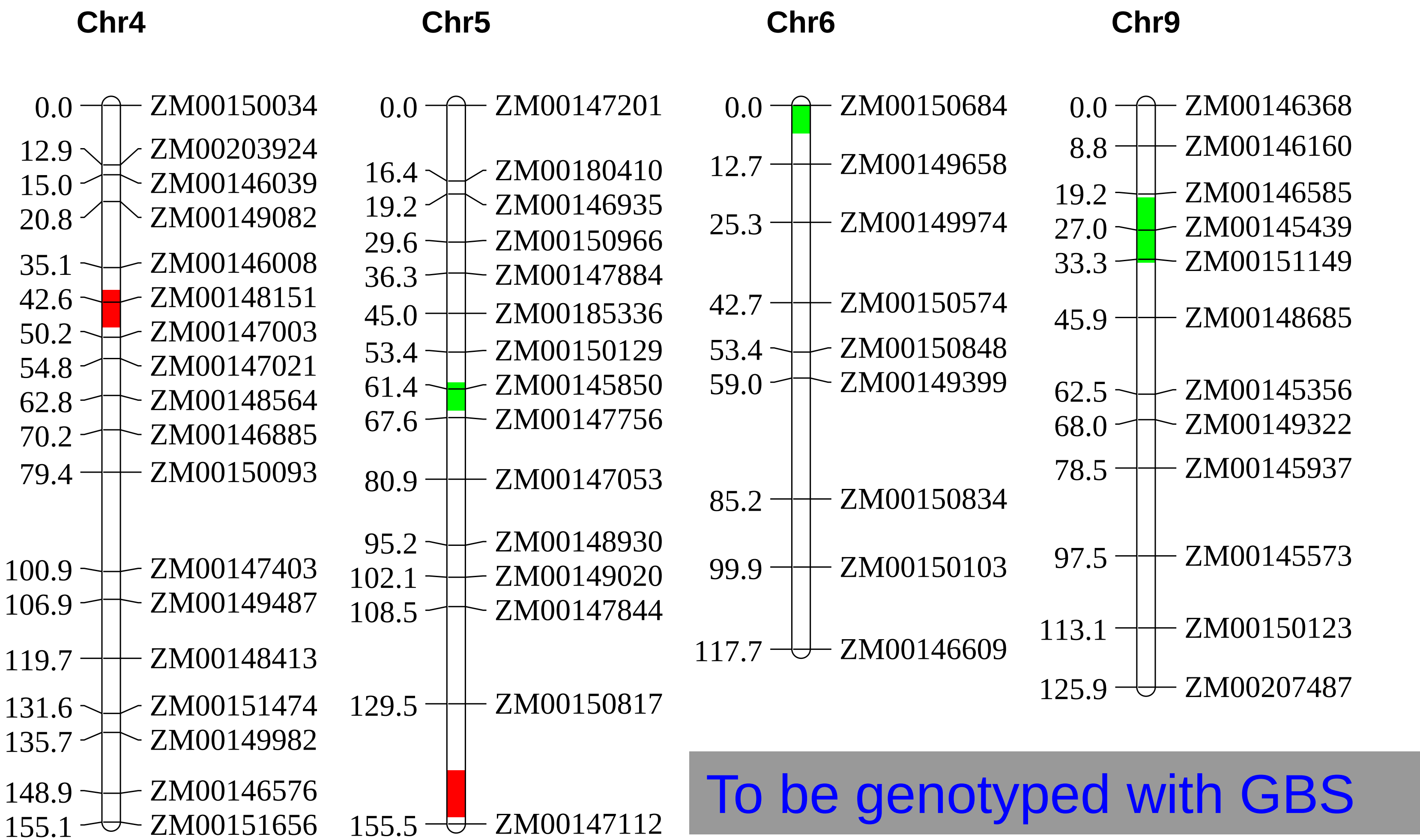
CIMMYT's ongoing efforts in identifying/ developing MLN resistant maize germplasm

- Hybrids currently in NPT in different countries
- Pre commercial hybrids from different projects
- Elite SC widely used in ESA
- Early and medium kits regional trials
- Elite inbred lines from different CIMMYT projects
- DTMA and IMAS association mapping panels
- Selected bi-parental mapping populations
- Commercial hybrids from different companies
- Selected landrace accessions from CIMMYT Gene Bank

Accelerating MLN resistant germplasm development
Molecular marker-assisted breeding

- Possible to identify major genomic regions influencing resistance to MLN
- CIMMYT-KARI team is presently undertaking GWAS and validation using biparental populations to identify molecular markers for MLN resistance
- Molecular marker-assisted backcrossing for conversion of selected elite but MLN-susceptible inbred lines into resistant versions.
- MABC, if some major QTL can be found, reduces time required several-fold (2-3 BCs instead of 6-7 BCs).

Preliminary QTL for MLN resistance (bi-parental popn)

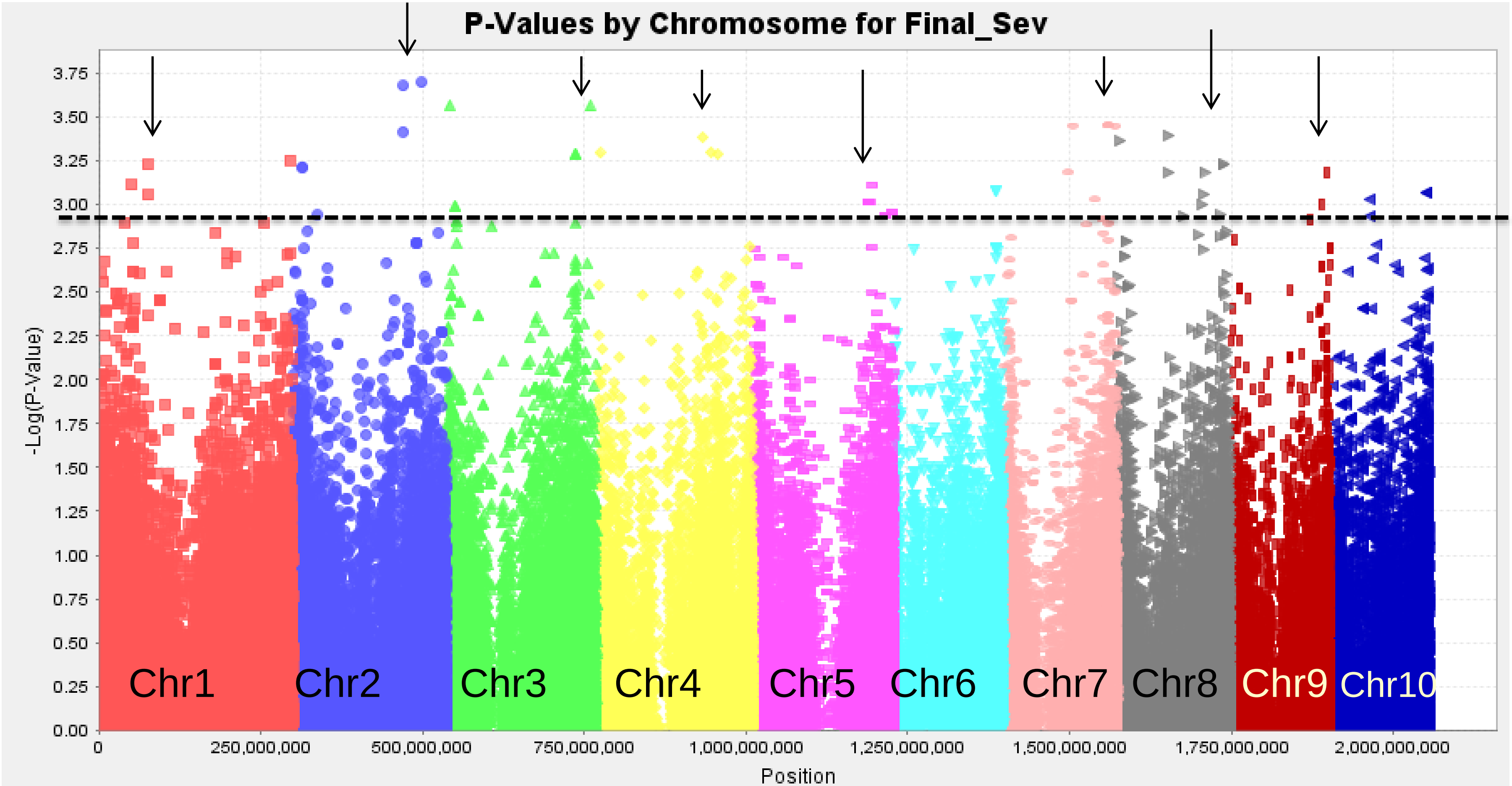


To be genotyped with GBS

	Chr4	Chr5	Chr6	Chr9
R^2	7.7%	2.5% & 5.4%	7.7%	4.2%
Source	CML444	CZL03014/CML444	CZL03014	CZL03014

Shaded regions indicate the confidence interval of the QTL

MLN disease severity (127,669 SNPs)



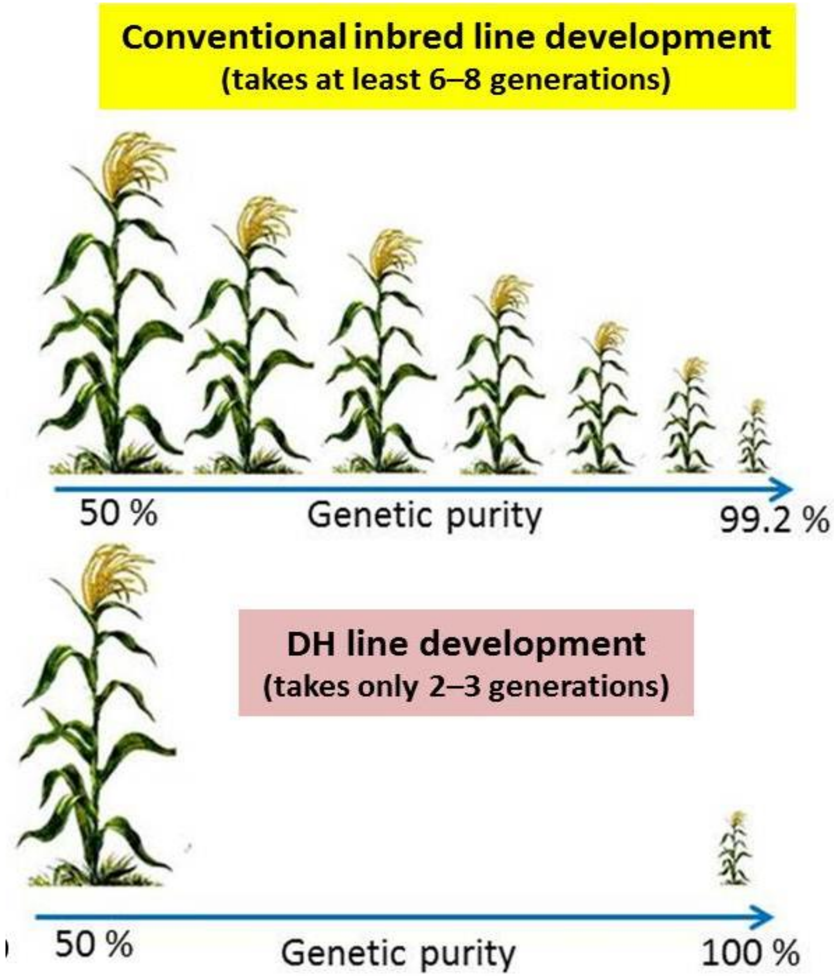
R^2 per significant marker = 8.1-17.6%

Chr	Mean R^2
1	10.4%
2	11.6%
3	9.9%
4	11.3%
5	9.5%

Chr	Mean R^2
6	10.7%
7	13.5%
8	10.5%
9	12.3%
10	12.9%

Accelerating MLN resistant germplasm development
Using doubled haploid (DH) technology

- A state-of-the-art maize DH facility is being established by CIMMYT in Kiboko Station; will be ready by Sept 2013.
- The DH technology, in combination with molecular markers, can help reduce by half the time taken for developing MLN resistant versions of existing elite susceptible lines.



Seed Systems Support

- Information on elite inbreds and pre-release hybrids with resistance (R) or moderate resistance (MR) to MLN under artificial inoculation conditions (besides natural disease pressure) shared with public and private partners in ESA, including Kenya, Tanzania, Uganda, Rwanda, Ethopioa, Zimbabwe, Zambia, Mozambique, Malawi and South Africa.
- Seed requests received from several partners – seed exchange will take place in July-August, with first priority to institutions in eastern Africa.
- Some promising hybrids in NPTs and some more in pipeline – emphasis on wider reach through non-exclusivity, till supply is more than the demand.

How can we better control MLN? Short-term

- Harmonizing maize plantings, and ensuring a maize-free period
- Promoting good agricultural practices, including crop rotation with non-cereals (e.g., legumes)
- A massive awareness drive, including farmers and extension agencies -> for effective local quarantine
- Seed companies/ seed units to ensure that seeds are treated with appropriate seed dressers at the recommended rates.
- Guidance to farmers on regime of MLN management, including pesticide application in the field

+ identification, fast-track release delivery of MLN resistant maize varieties

MLN Epidemiology:
Unanswered Questions

- Is MLN in eastern Africa only due to MCMV + SCMV or due to MCMV + any other member of Potyviridae in different countries?
- What alternate hosts of MLN-causing viruses are prevalent in the region? How best to control them?
- What are the primary or most active insect-vectors spreading the disease?
- How frequent is seed transmission of viruses, especially MCMV? When is seed transmission most likely to happen?

Table 1. Plants tested for susceptibility to strains of MCMV (Scheets 2004).

Immune genera[1]	Susceptible genera	Genera with both immune and susceptible species
Axoponus	*Andropogon*	*Agropyron*
Chloris	*Avena*	*Bromus*
Elymus	*Bouteloua*	*Cenchrus*
Festuca	*Buchloe*	*Cynodon*
Lolium	*Calamovilfa*	*Dactylis*
Oryza	*Eleusine*	*Digitaria*
Paspalum	*Eragrostris*	*Echinochloa*
Poa	*Euchlaena*	*Panicum*
Saccharum	*Hordeum*	*Phalaris*
	Secale	*Setaria*
	Sorgastrum	*Zea*
	Sorghum	
	Spartina	
	Tripsacum	
	Triticum	

[1]Status of hosts listed in this table are a result of experimental inoculations, not natural field infection.

Nelson et al. 2011

Understanding MLN Insect-vector Dynamics

- Survey and identification of vectors endemic to eastern Africa that are capable of transmitting MLN-causing viruses, especially MCMV and SCMV
- Determining patterns of insect-vector movement and MLN disease development under natural conditions.
- Understanding of the effects of novel seed treatment technologies on the biology of insect-vectors transmitting MLN-causing viruses, and virus transmission competence.

A competitive grant call has been announced recently under the MAIZE CRP.

Aphids

Thrips

Leaf hoppers

MLN-free Germplasm Exchange

- We can possibly exchange seed produced from a MLN-free location (e.g., Kiboko) in a MLN-endemic country (e.g., Kenya) to other MLN-endemic countries in eastern Africa (e.g., Tanzania and Uganda), but NOT to any country where MLN has not been reported so far, including Ethiopia and southern African countries.
- Seed for international shipment from an MLN-endemic country can only be produced in a MLN-free location, and following due diligence.
- MLN Quarantine Site to be established very soon in CIMMYT-Zimbabwe.
- Comprehensive protocols being developed by CIMMYT for rigorous compliance in ESA.

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- NARS and seed company partners across eastern and southern Africa
- USDA/OSU (Peg Redinbaugh and her team)
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The pessimist complains about the wind.
The optimist expects it to change.
The realist adjusts the sails.

- William A. Ward