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Maize based Food Security in the Developing World

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CGIAR RESEARCH PROGRAM ON Maize

Maize is the preferred staple food for:

- About **900 million poor consumers** (who survive on <$2 income per day)
- **120-140 million** poor families
- About **73 per cent** of the maize area worldwide is located in the developing world.

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Maize in Sub-Saharan Africa

- Of the 22 countries in the world where maize forms the highest percentage of energy in the national diet, 16 are in Africa.
- Consumption highest in ESA; Lesotho, Zambia, and Malawi consume >50%, surpassing Mesoamerican countries, where the crop originated.

Country	Maize intake, g/capita/day	Maize, % daily energy intake	Maize, % daily protein intake
Lesotho	438	55.4	52.0
Zambia	320	51.8	54.9
Malawi	359	51.2	52.5
Zimbabwe	323	41.2	43.8
South Africa	288	29.6	28.1
Kenya	222	33.3	30.7
Tanzania	162	25.7	25.3
Swaziland	166	24.0	23.8
Benin	170	19.8	22.2
Mozambique	140	19.5	28.2
Namibia	143	17.8	16.5
Ethiopia	114	19.5	15.9

Source: Nuss and Tanumihardjo (2015)

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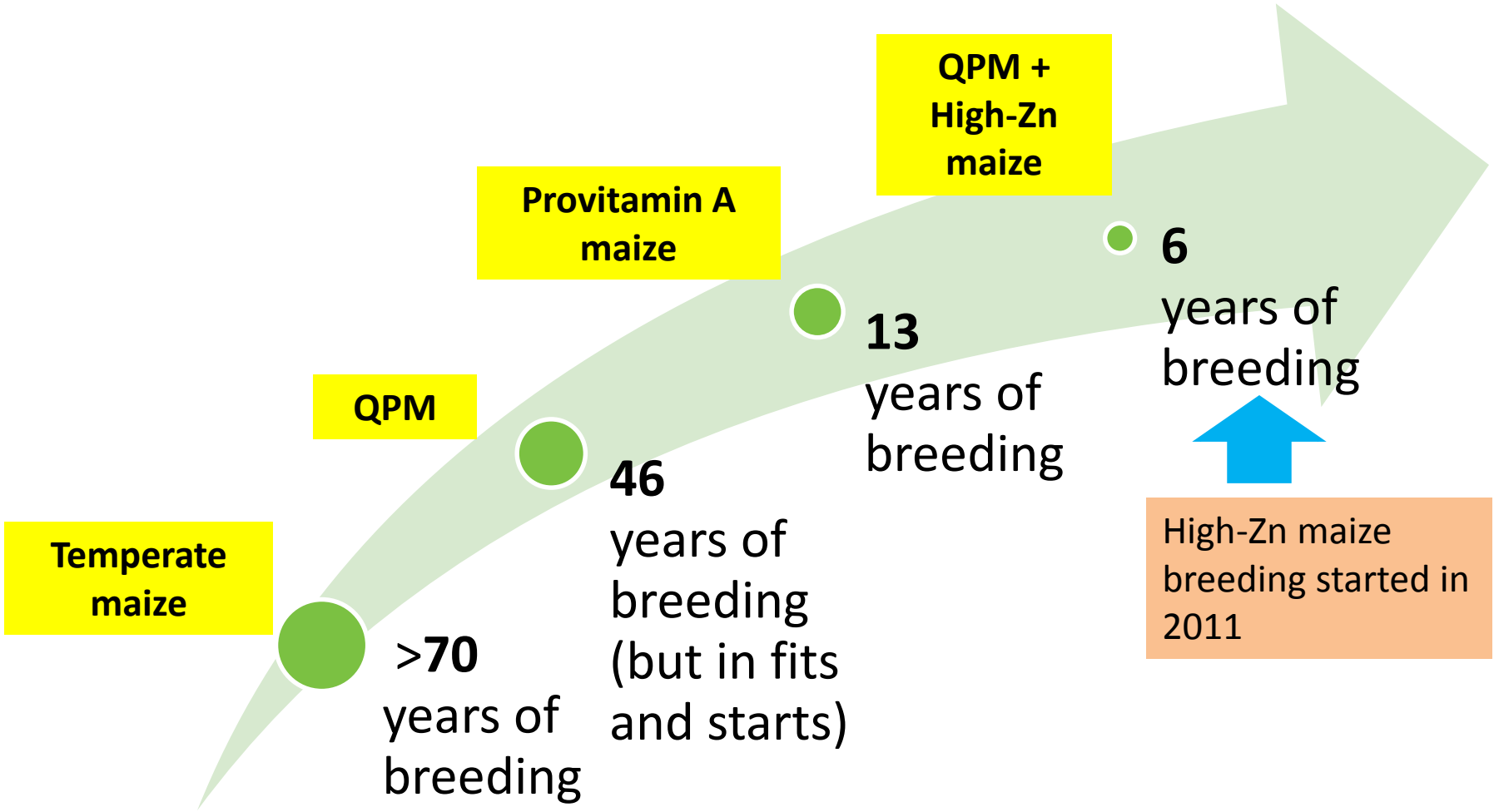
Breeding for Biofortified Maize at CIMMYT



Nearly 50 years after discovery of nutritional benefits of *opaque-2*, and 15 years after World Food Prize to Dr SK Vasal and Dr Evangelina Villegas…

- Array of QPM varieties released and deployed worldwide
- Large efforts on biochemical analyses at CIMMYT, evaluating more than 10,000 QPM samples in the last 5 years
- Several studies on socio-economics and impact assessment of QPM, especially in Sub-Saharan Africa (SSA).

Prof. Oliver Nelson

Dr. S.K. Vasal

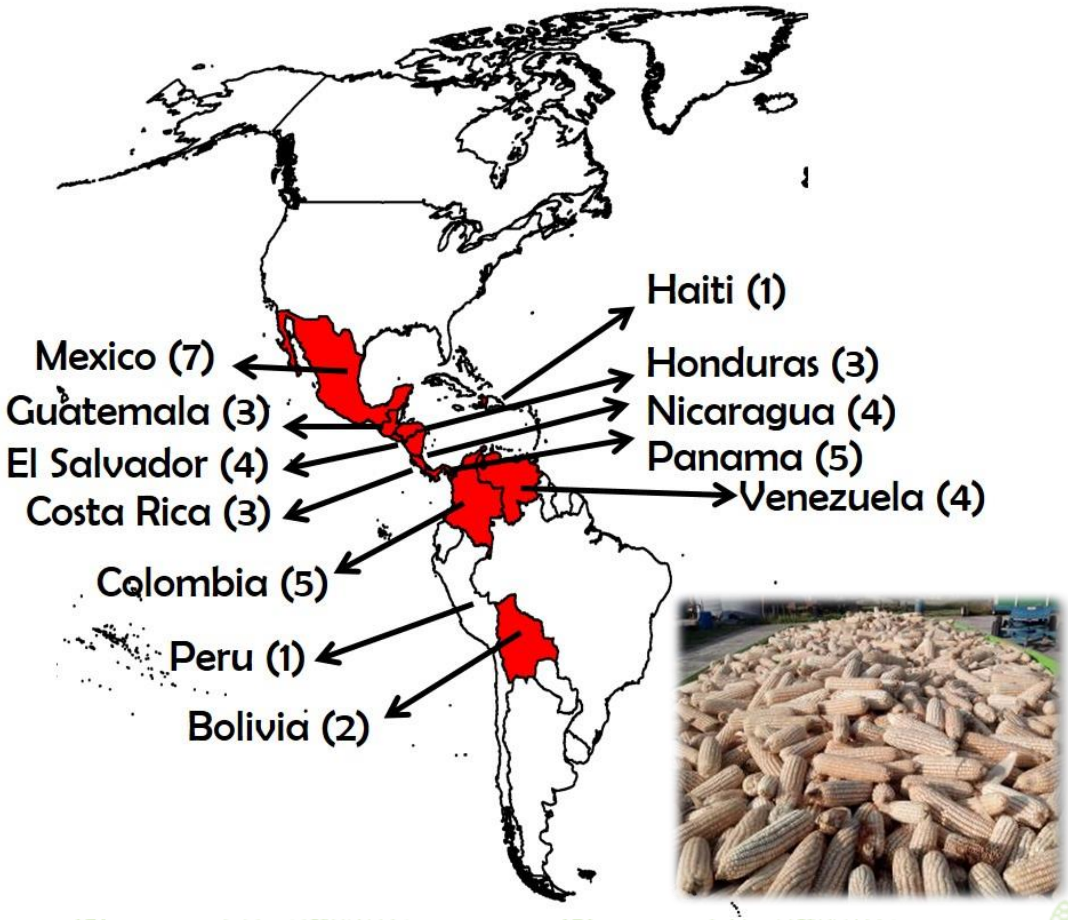
Dr. Eva Villegas

Estimated adoption of QPM varieties

- **~1 million ha in sub-Saharan Africa**, with Ghana and Uganda together accounting for ~50% of this, and 18 other countries accounting for the rest.
- **~150,000 ha in 12 Latin American countries**, especially Venezuela, Guatemala, Mexico, Honduras, Bolivia, and Colombia.
- **~250,000 ha in Asia**, with ~80-90% of this area in selected provinces of China, and the rest in other Asian countries, including India, Nepal, Philippines and Indonesia.

QPM in Latin America

>50 QPM varieties based on CIMMYT germplasm released in LatAm since 2003



Late Hugo Cordova
CIMMYT Distinguished Scientist, with major contributions to QPM deployment in LatAm

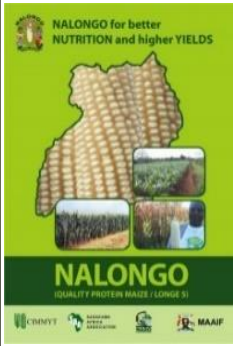
Several QPM varieties released in Sub-Saharan Africa

Ethiopia	BHQP542; BHQPY545; BHQP548; Melkassa 6Q; MH138Q; Melkassa-1Q; **AMH760Q**
Kenya	KH531Q; KH631Q; WSQ104
Tanzania	TAN H613Q; Lishe-H1; Nata K6Q; MAMS H0913; Lishe-H2
Uganda	Longe-5 (Nalongo); Salongo
Ghana	**Obatanpa**; Mamaba; Cida-ba: Daba-ba; Aziga (yellow); Akposoe; Etubi; Golden Jubilee; Enibi; Abontem; Omankwa
South Sudan	Longe-5 (seed import largely marketed in South Sudan)
Mozambique	Sussuma
Burkina Faso	Espoir (Obatanpa)
Zimbabwe	ZS261Q

Late Twumasi-Afriye
CIMMYT Breeder, with major contributions to QPM varietal development and deployment

NuME Project in Ethiopia

Intensive Efforts on QPM Popularization



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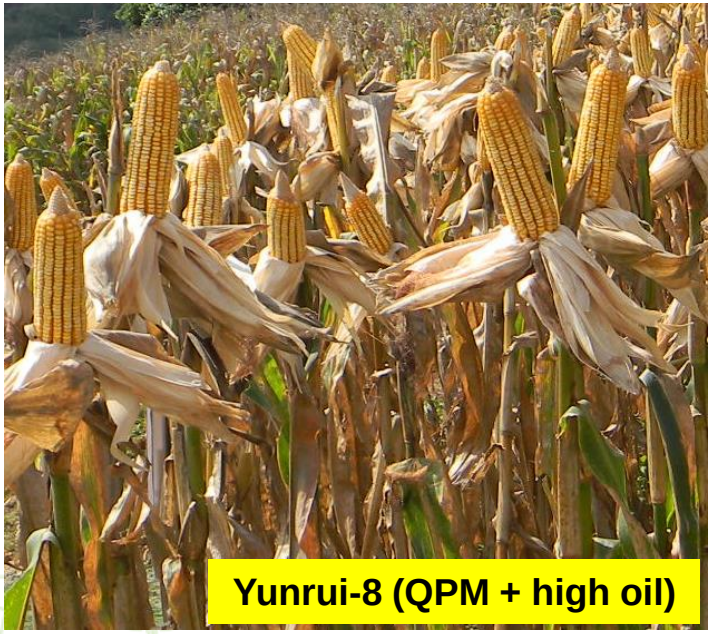
QPM in China: Pockets of Impact

- Demonstrated impact in Guizhou, Yunnan and Guangxi Provinces, targeting development of animal husbandry + nutritional well-being of communities living in the less-developed mountainous areas
- **Focus mostly on combination of nutritional traits** (e.g., QPM + high oil)
- **QPM seed villages** successfully being implemented


Yunrui-1 (QPM + GLS resistance)


Yunrui-8 (QPM + high oil)

QPM in the Hills of Nepal and Bhutan


Poshilo Makai-1

Nepal

- **"Poshilo Makai-1"**, first QPM variety (white maize) released in Nepal, based on CIMMYT germplasm.
- **Community-based seed production** under the Hill Maize Research Project (HMRP) in Nepal (funded by SDC and USAID)

Bhutan

- ~37,000 households cultivate maize
- "Chaskarpa", a GLS-resistant yellow QPM variety S03TLYQAB05 introduced from CIMMYT-Colombia in Bhutan, released in 2012; **community-based seed production.**

Three New QPM Hybrids released in India in 2017 using MAS

Maize: Pusa HM4 Improved

(Hybrid)

Tryptophan 0.91%

Lysine 3.62%

- Contains 0.91% tryptophan and 3.62% lysine which is significantly higher than popular hybrids (0.3-0.4% tryptophan and 1.5-2.0% lysine)
- Grain yield: 64.2 q/ha
- Maturity: 87 days
- Adaptation: *Kharif* season in Punjab, Haryana, Delhi, Uttarakhand (Plain), Uttar Pradesh (Western region)]
- Developed by ICAR-Indian Agricultural Research Institute, New Delhi

Year of release: 2017

Maize: Pusa HM8 Improved

(Hybrid)

Tryptophan 1.06%

Lysine 4.18%

- Rich in tryptophan (1.06%) and lysine (4.18%) as compared to 0.3-0.4% tryptophan and 1.5-2.0% lysine in popular hybrids
- Grain yield: 62.6 q/ha
- Maturity: 95 days
- Adaptation: *Kharif* season in Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu
- Developed by ICAR-Indian Agricultural Research Institute, New Delhi

Year of release: 2017

Maize: Pusa HM9 Improved

(Hybrid)

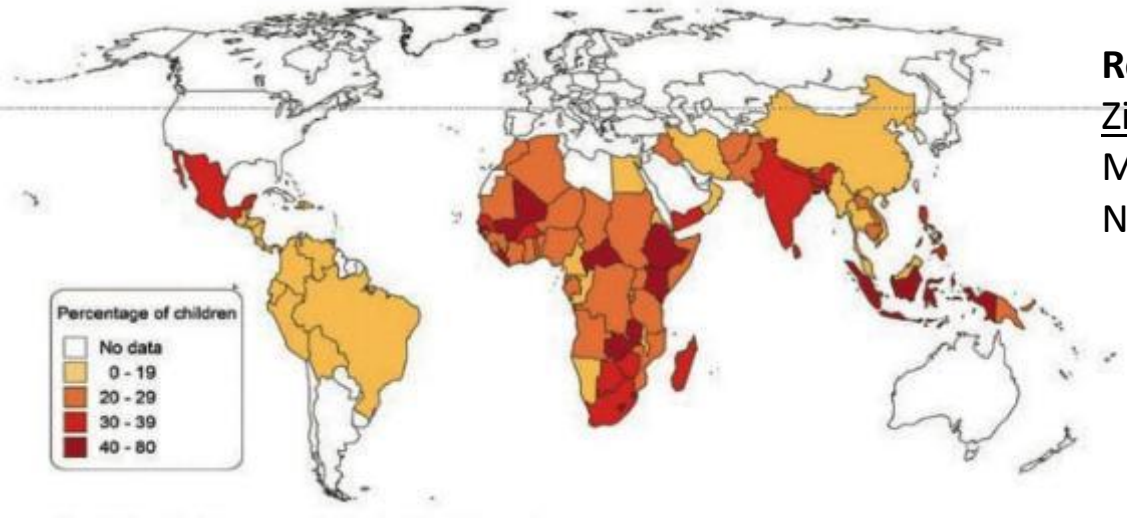
Tryptophan 0.68%

Lysine 2.97%

- Contains 0.68% tryptophan and 2.97% lysine compared to 0.3-0.4% tryptophan and 1.5-2.0% lysine in popular hybrids
- Grain yield: 52.0 q/ha
- Maturity: 89 days
- Adaptation: *Kharif* season in Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern region) and West Bengal
- Developed by ICAR-Indian Agricultural Research Institute, New Delhi

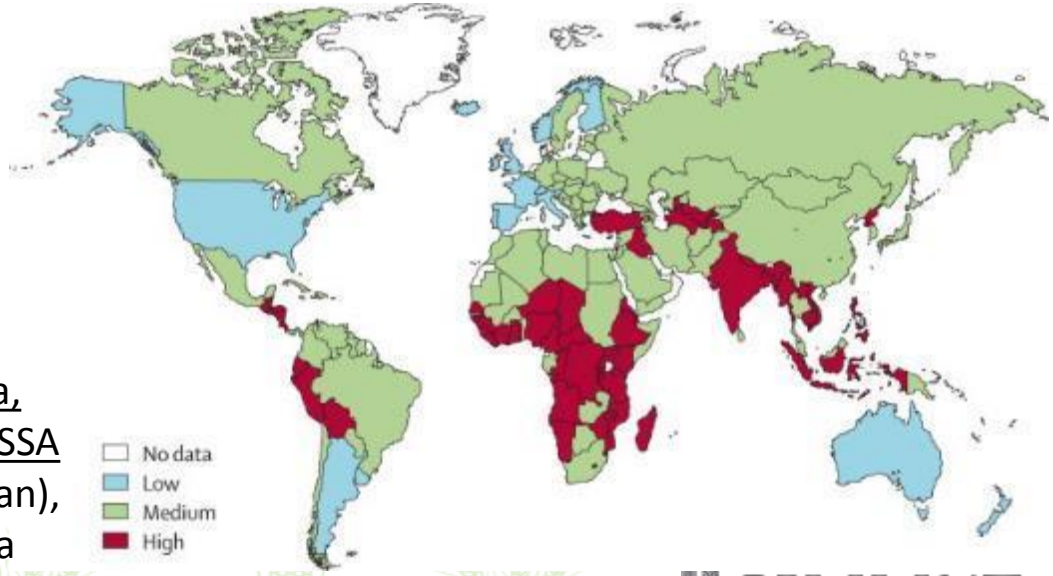
Year of release: 2017

Vitamin A deficiency, children <5 years



Red Countries: Ethiopia, Kenya, Zambia, Zimbabwe, Botswana, South Africa, Madagascar, Mali, C.A.R., Mexico, India, Nepal, Bangladesh, Indonesia…

Zn deficiency, children <5 years



Red Countries: Guatemala, Nicaragua, Ecuador, Peru, Bolivia, Almost entire SSA (except Zambia, Botswana, Mali, Sudan), and most countries in South & SE Asia

CIMMYT

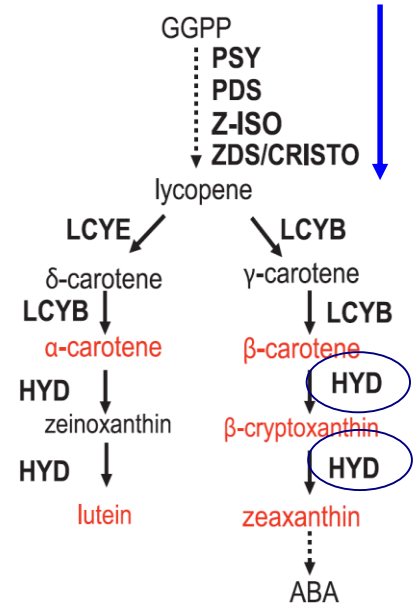
Using markers for trait enrichment in maize: PROVITAMIN A is a success story!

First wave of PVA hybrids

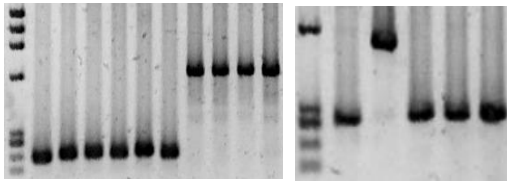
- PVA content (6-8 ppm)

Second wave of PVA hybrids

- Higher PVA content (10-12 ppm)
- Good grain yield (6 t/ha)
- Earlier maturing
- More resistant to ear rots
- Marginally better stalk lodging



CrtRB1 has an overriding effect and can bring up to 10-fold improvement in ProA content on its own!



Harjes et al., 2007; Yan et al. 2010; Babu et al., 2013

Current breeding efforts

- Using CrtB1 marker
- Better stalk lodging
- Bigger ears
- Larger kernel size
- Developing high BCX germplasm

HarvestPlus
Breeding Crops for Better Nutrition

CIMMYT

ProVA in Zambia

2013: first wave - three CIMMYT-derived varieties deployed

2015: second wave - eight varieties deployed and 460 tons produced for commercial sale

2016: ~100,000 households growing and eating proVA maize

2013

6-8 ppm

2016

12-14 ppm

HarvestPlus
Breeding Crops for Better Nutrition

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高维生素A源玉米杂交组合YR506
High Pro-vitamin A Hybrid Maize YR506
总VA前体含量 Total Pro-VA Content 23.63 ug/g
总类胡萝卜素含量 Total Carotenoid Content 37.56 ug/g
2010年云南省农科院品比试验：比普通玉米杂交种兴黄单892增产10%左右
Variety Test in 2010: about 10% yield over check Xinghuangdan 892 –
A Yunnan popular normal maize hybrid
2011年云南省多点试验：植株清秀健壮，株高、穗位适中，待收获测产
Multi-location Trial in 2011: Perform well, will be harvested soon.

Maize: Pusa Vivek QPM9 Improved

(Hybrid)

Provitamin-A 8.15 ppm

Lysine 2.67%

Tryptophan 0.74%

- Country's first provitamin-A rich maize
- High provitamin-A (8.15 ppm), lysine (2.67%) and tryptophan (0.74%) as compared to 1.0-2.0 ppm provitamin-A, 1.5-2.0% lysine and 0.3-0.4% tryptophan content in popular hybrids
- Grain yield: 55.9 q/ha [Northern Hills Zone (NHZ)] and 59.2 q/ha [Peninsular Zone (PZ)]
- Maturity: 93 days (NHZ) and 83 days (PZ)
- Adaptation: *Kharif* season in J&K, Himachal Pradesh, Uttarakhand (Hill region), North Eastern states, Maharashtra, Karnataka, AP, Telangana and Tamil Nadu
- Developed by ICAR-Indian Agricultural Research Institute, New Delhi

Year of release: 2017

India's first Provitamin A-enriched maize hybrid "Pusa Vivek QPM9 Improved" released in 2017

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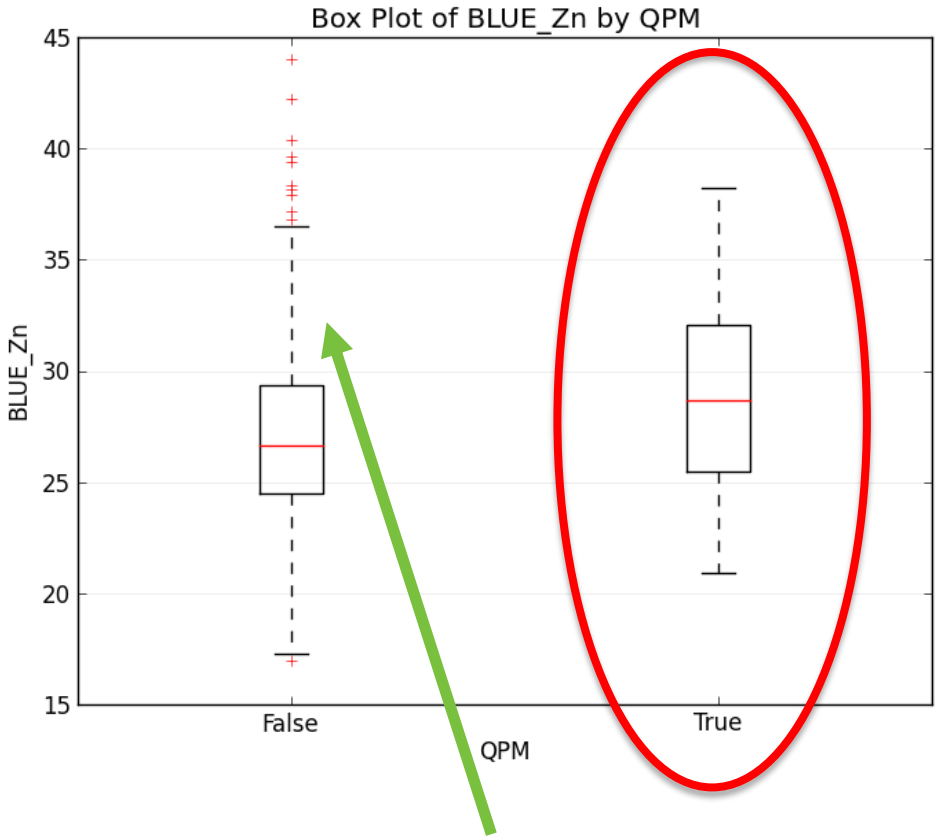
High kernel-Zn has been observed mainly in QPM background.

Inbred	Mean Zn (ppm)
CML264	29.86^{b,a,c}
CML264QPM	34.25^{a}
CML451	**31.46^{b,a}**
CML451QPM	31.53^{b,a}
CML247	30.63^{b,a,c}
CML247QPM	26.61^{d,c}
CLO2450	27.55^{b,d,c}
CLO2450QPM	30.46^{b,a,c}
CML273	23.98^{d}
CML273QPM	29.41^{b,d}
CML254	27.24^{b,d,c}
CML254QPM	28.56^{b,d,c}



Possible to identify and enhance the levels of kernel Zn in non-QPM genetic backgrounds.

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High-Zn Maize Varieties (>33 ppm) released in Latin America

- **2017**: Two high-Zn maize varieties released in Honduras
- **2018**: One high-Zn variety released recently in Colombia
- By May 2018, one more high-Zn hybrid to be released in Colombia, and two varieties in Guatemala

HarvestPlus
Breeding Crops for Better Nutrition

CIMMYT

Dual-purpose Maize

CIMMYT germplasm suitable for improved stover quality

Hybrid	IVOMD	GY (t/ha) under heat stress
ZH15436	53.65	4.42
ZH15437	54.08	5.85
ZH15439	53.65	5.14
ZH15445	53.79	5.90
ZH15377	53.65	5.21
ZH141199	55.00	4.34
CAH1511	54.52	6.06
ZH141593	55.99	4.50
VH112887	54.94	6.82
VH123001	55.63	6.84
VH123050	53.63	6.61
31Y45	53.60	4.26
Bio9544	53.86	5.22
D2244	53.57	4.62

In vitro digestibility (IVOMD)

CIMMYT-India + ILRI-Hyderabad

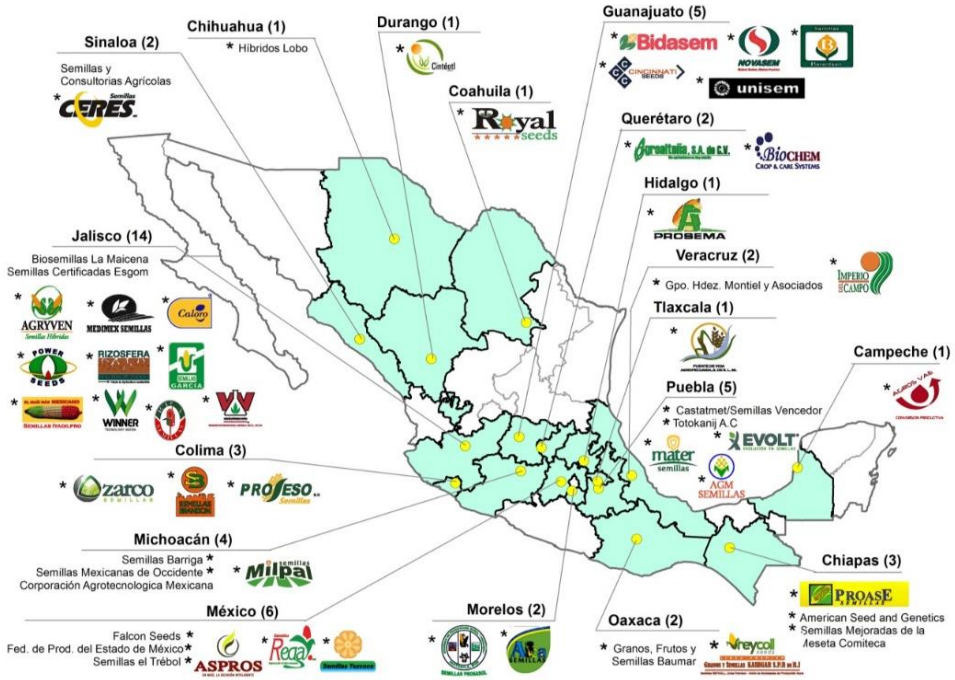
CIMMYT-ILRI study shows that there is possibility to improve stover quality without compromising on grain yield.

We will have to explore strategic partnerships to develop and deploy dual-purpose maize in Africa, Latin America and Asia.

CIMMYT

Partnership with >200 local, regional and large seed companies in Africa, Asia, and Latin America

- Diverse products for diverse ecologies and markets
- Diverse partners with diverse capacities and germplasm needs (and trait combinations)



Maize Nutritional Quality Enrichment

What have we done well so far…

- Developing and releasing a good number of QPM varieties worldwide through CGIAR-NARS partnership
- Strong pipeline of provitamin A-enriched maize varieties, especially in SSA (HarvestPlus)
- Effective use of molecular markers in breeding for QPM and provitamin A (CGIAR and NARS, especially in Asia)
- Significant progress in developing and releasing high Zn-QPM varieties, especially in Latin America
- High-throughput phenotyping protocols

Maize Nutritional Quality Enrichment

What needs to be done

- Bringing greater awareness among the white maize-consuming communities about nutritional benefits of high-Zn and provitamin A
- Mainstreaming provitamin A and high-Zn traits into elite white germplasm for targeted agro-ecologies in SSA, LatAm and Asia
- Effectively converging improved agronomy with biofortification strategy in the nutritional enrichment strategy
- Forging stronger partnerships with the private sector, especially agri-food sector players, for stimulating demand for nutritionally enriched maize products

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Maize Lethal Necrosis (MLN) in eastern Africa (since 2011)

- Prevalent in **Kenya, Tanzania, Ethiopia, Uganda, and Rwanda**
- Caused by co-infection of maize by **MCMV + SCMV** in eastern Africa
- **Transmitted by insect-vectors and virus-contaminated seed**

Fall Armyworm across Africa (since 2016)

- Confirmed to cause damage in **30 countries across Africa**
- **Rapid migration** from West Africa to southern Africa and eastern Africa since 2016
- **Extensive damage on maize crop**

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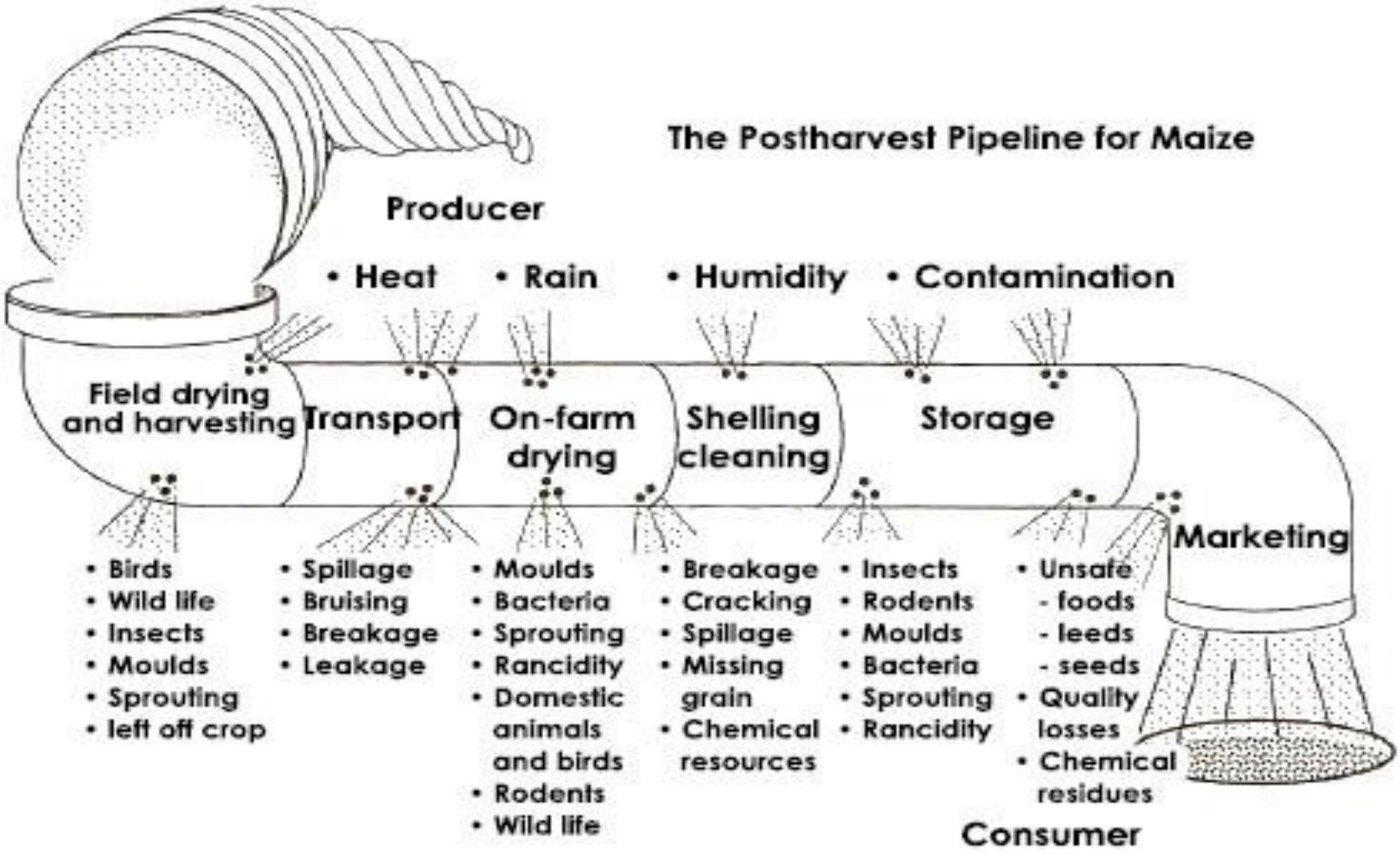
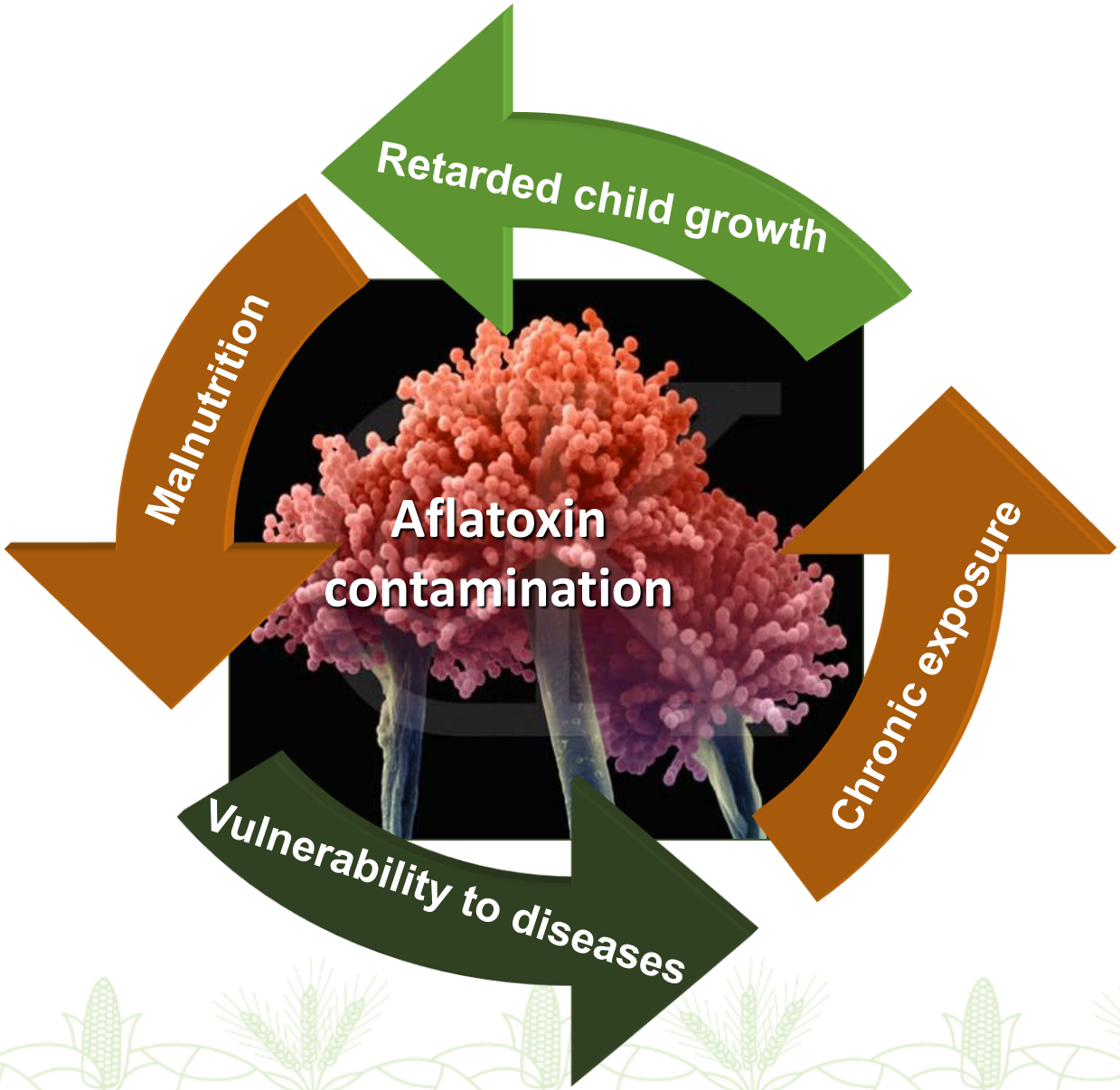
Post-harvest Pipelines are far from optimal…



Aflatoxin contamination is a major concern…



Human and animal exposure concerns plus **Trade restrictions**

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Aflatoxin Management in Maize Value Chains

Exciting advances:

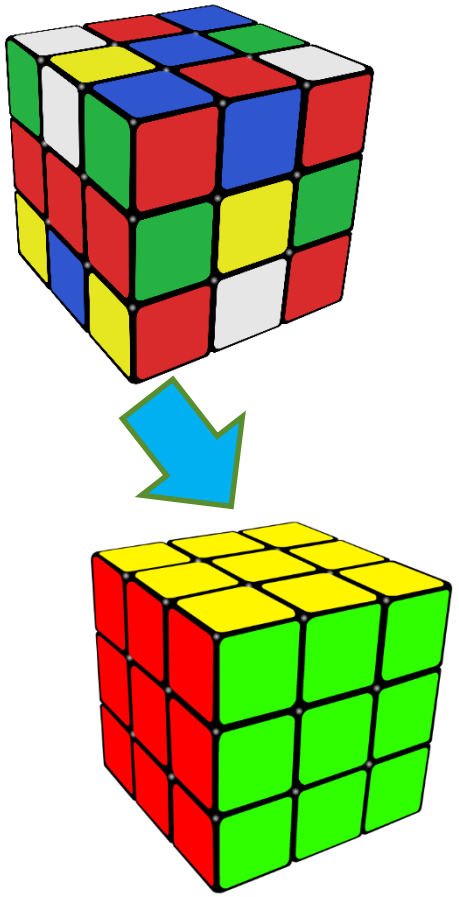
- Aflasafe technology development and deployment (IITA, with African partners)
- Identification and use of aflatoxin-resistant germplasm sources (CIMMYT; IITA; USDA-Mississippi)
- Development of new detection and diagnostic tools that are cheaper, more reliable, and more easily used in the field

- Continued need for multidisciplinary and comprehensive research to inform policy and to test potential solutions.
- Need to evaluate various solutions within the context of the entire supply chain.
- Identify where market incentives can support improved food safety and better health outcomes for poor consumers.

CIMMYT

Enabling policies and institutional innovations are just as important as technological innovations

- **INTEGRATE** – research, extension, education, training
- **CONNECT** – farmers, producers, entrepreneurs, consumers
- **STRENGTHEN** – the entire maize value chain innovation system



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Thanks!

www.MAIZE.org

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