Progress in maize variety development and seed systems
Pathways for maize variety release

Breeding new maize varieties

Regional Trials, WWT, ROFT

Variety release, registration (DUS, VCU)

Basic & Certified Seed Production

Varietal Promotion and dissemination

CIMMYT, NARS, large Seed companies

CIMMYT, NARS, Seed companies

NARS Seed companies

NARS (for basic seed only), Seed companies, CIMMYT (initial seeds)

Seed companies NARS, CIMMYT
CIMMYT’s maize Germplasm Bank contains over 28,000 unique collections of maize seed and related species from 88 countries.

The collections are a source of diversity to breed for traits such as heat and drought tolerance, resistance to diseases and pests, and to improve grain yield and grain quality.
Variety development

- Selection from indigenous germplasm
- Hybridization and selection
- Tissue culture
- Mutation breeding
- Marker assisted selection
- Bioinformatics
- Double haploid
Trait prioritization/Trait combinations

**Foliar Diseases**
- MSV, GLS, ET, PLS, PS

**Ear Rots/Aflatoxins**
- Fusarium, Diplodia

**High Yield Potential**
- Local and Introductions
- Density response

**Striga**
- Specific in some areas

**MLN**
- New serious challenge

**Pests**
- Field Pests
- Storage Pests

**Producibility**
- High yielding females
Trait prioritization/Trait combination

**Drought**
- Flowering and Grain Filling Drought Stress

**Low N**
- Continues to be a problem

**Heat**
- Heat Stress Alone
- Heat Stress Combined with Drought Stress

**Low P/Acid Soils**
- Phosphors Hunger Acid soils – underestimated problem

**Pro A Maize**
- Potential reduction in Industrial Bio-fortification

**QPM**
- Renewed Demand for QPM

**High Zn Maize**
- Combined with QPM and/or Pro-A
Modelling – influencing the breeding pipeline

2.1°C increase by 2050
Reduce maize yields by 11% in Zimbabwe

Commercial varieties very sensitive to heat

First heat tolerant varieties commercialized in southern Africa in 2014

Cairns et al. 2012, 2013a and b, Magorokosho et al. in preparation
Modelling – influencing the breeding pipeline

CIMMYT varieties yielded almost double the most popular commercial variety during the El Niño season on 2015/16

(1.5 Mg ha\(^{-1}\) compared to 2.9 Mg ha\(^{-1}\))

Setimela et al. 2017b
Climate smart, nutritious maize

Borlaug Fellowship
CIMMYT & Cornell (Christine Diepenbrock and Prof Mike Gore)

Genetic stability of pro-vitamin under heat stress

Effects of heat stress on pro-vitamin A concentration
Accelerating variety replacement

- Stage III Trials, Across Breeder combinations, Regional Trials
- Line finishing, Quality control
- Product Profiles

- White hybrids (SC, 3-way, Double-cross, OPV)
- Yield improvement compared to the best commercial checks:
  - Managed drought: 45 kg/ha/year
  - Low N: 45 kg/ha/year
  - Optimal: 110 kg/ha/year
  - Per se female yield: 45 kg/ha/year
  - MLN: 250 kg/ha/year

- General Product Requirements
  - Maturity: early, intermediate and late
  - Disease resistance: GLS, NLB, MSV and MLN
  - Agronomic traits: root lodging, maturity, husk cover
  - Grain Texture: flint to flinty-dent
  - Color

- Regional Trials (Southern Africa Example)
  - Early Maturing: 50 entries
  - Medium Maturing: 70 entries
  - Late Maturing: 45 entries
  - OPV: 50 entries
  - Parent Trials (Inbreds, OPVs)
  - Nutritious maize trials
  - Approx. 600 sets distributed annually

- Commercial Checks
  - SC301, SC403, SC513, SC637, SC727
  - PAN53, PAN7M-81
  - PHB30G19, PHB3253
Regional trial distribution network

CIMMYT International Testing in cooperation with partners
Maize •
Genetic gain in Eastern and Southern Africa

Genetic gain under optimal conditions (Mg ha$^{-1}$ yr$^{-1}$)

Genetic gain in hybrids
- Optimal = 1.4%
- Managed & random drought = 0.85%
- Low nitrogen = 0.62%
- Maize streak virus = 2.2%

Comparable with other breeding programs worldwide

Masuka et al. 2017a and b
However maize yields remain low

Maize area has increased by 245%

Maize production in sub-Saharan Africa increased 5-fold since 1960s

Adapted from FAO, 2017
Mechanization and Automation of Breeding Operations

Nursery Rows 15,000 -> 50,000
Genotypes tested 25,000 -> 200,000
Annual trial rows >100,000 -> 500,000
Testing environments 5 -> 15+
Locations 20 -> 60+
Data Turnaround Time 80 -> 20

• Efficiencies realized in seed preparation
• Efficiencies realized in electronic field data collection
• Efficiencies realized in trial harvest processing
Seed production research

Single Cross female yields, 2013

- SC727
- CML539/CML444
- CML536/CML312
- CML312/CML442
- CML312/CML444
- CML312/CML443
- CML538/CML539
- CML444/CML489
- CML539/CML197
- CML540/CML442
- CML395/CML444
- CML547/CML444
- CML442/CML539
- CML509/CML540
- CML539/CML540
- CML537/CML312
- CML536/CML538

Average Yield (t/ha)
Percent proportion maize varieties by region

1700 maize varieties have been released between 1950-2014

Abate et al., 2017
2016 maize releases

Varieties commercialized by CIMMYT partners with traits preferred by smallholder farmers
Variety Releases

2007-2014

>200 drought-tolerant and nutrient use-efficient maize varieties were released by >100 companies in 14 countries.

First MLN tolerant varieties commercialized in east Africa in 2016.

100,000 families growing and eating pro-vitamin A enriched maize.

First heat tolerant varieties commercialized in southern Africa in 2014
Accelerating variety replacement
Seed trade

- Seed market is valued at US$ 800 million which US$ 500 million is maize
- US$250 million horticulture (2% world share)
- Adoption rate of improved seed is estimated at 40%
Many of the hybrids on the market in have CIMMYT germplasm

- CIMMYT is the largest contributor of improved maize germplasm annually as international public goods.
- Over 54% of publicly bred maize varieties released in the developing world are reported to have CIMMYT's elite maize germplasm.
The Seed: a living organism

- Higher value = more care & inputs
- Higher quality & genetically pure
  - Greater care in selection
  - Careful preparation of seed production fields
- Consider seed sales, labor availability
Seed Classes

- **Breeders’ Seed**
  - Controlled pollination
  - Small quantities

- **Pre-Basic/Basic Seed**
  - Extra-isolated fields
  - Strict quality standards

- **Certified Seed**
  - Isolated fields
  - High quality standards

Seed quality declines from Breeders Seed through to Certified Seed
Variety maintenance

Increasing pure seed stock of a variety forever while avoiding contamination or genetic drift
Applications of molecular markers in QA/QC

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1. Identification of genetic purity
2. Parent-off spring identity
3. Genetic purity of hybrid seed lots
4. Validation of crosses in nurseries
5. Trait-specific testing of seeds

Capacity building of partners

10,000 days training given each year.

Technician Training
Breeders Training
Visiting Scientists
Ph.D./MSc students

More than 1,000 scientific and professional alumni around Africa.

Technician Training in Zimbabwe

Breeders Training in Zambia
Conclusions

• Efficiency gains made in the last decade
• New methods and tools incorporated into breeding
• New emerged challenges tackled with tangible outputs
Thank you!