Heat Stress Tolerant Maize for Asia (HTMA)

A Public-Private alliance for development & deployment heat stress-resilient maize hybrids in South Asia

GLOBAL DEVELOPMENT ALLIANCE (GDA)

FEED THE FUTURE
The U.S. Government’s Global Hunger & Food Security Initiative

USAID
FROM THE AMERICAN PEOPLE
Climate change effects in India
Mean surface temperature over last 100 years (1901 – 2011)

Significant departure from average, during last decade!

Courtesy: Dr. S.D. Attri, DDG-M, IMD, New Delhi, India
Workshop on “Climate Smart Agriculture”, 11-12 April, 2012, Bangkok
Effect on Crop production

- If current trends persist until 2050, the yields of major crops in South Asia will decrease significantly:
  - Maize (-17%),
  - Wheat (-12%) and
  - Rice (-10%)

  *due to of climate change-induced heat and water stress.*

- Resulting food scarcity will lead to higher prices and reduced caloric intake across the region.

*Building Climate Resilience in the Agriculture Sector of Asia and Pacific (IFPRI and ADB, 2009)*
Heat stress
on maize in Asian Tropics

- **Intensive cereal system:**
  *Summer maize – a niche for third maize crop but prone to face heat stress.*

- **Climate change effects** –
  *Mid-season heat (+drought) stress in main maize crop season (monsoon)*
New project launched: Heat Stress Tolerant Maize for Asia

South Asian farmlands have been increasingly experiencing climate change related weather extremes. A report from the Asian

is directly dependent on maize yields and negatively affected by crop failures. To develop and deploy heat stress resilient, high-yielding maize hybrids for vulnerable regions in South Asia, the HTMA project will build upon CIMMYT’s elite abiotic

Perez, and Raman Babu discussed the GS concept, its application in breeding programs, and data analysis and management for fast-track breeding progress and product development. The meeting included a presentation on the FTF initiative by Larry
Heat Stress Tolerant Maize for Asia (HTMA)

Alliance partners:

Public sector NARS:
- Bangladesh Agricultural Research Institute (BARI), Bangladesh
- Bihar Agriculture University (BAU), Sabor, India
- Maize and Millet Research Institute (MMRI), Pakistan
- National Maize Research Program (NMRP), Nepal
- University of Agricultural Sciences (UAS), Raichur, India

Seed companies:
- Pioneer Hi-bred, India
- Kaveri Seed Company Ltd., Hyderabad, India
- Ajeet Seeds Ltd., Aurangabad, India
- Vibha Seeds, Hyderabad, India

International institutions:
- Purdue University, USA
- United State Agency for International Development (USAID)
- CIMMYT-Hyderabad, India
HTMA
Specific Objectives:

1. **Dissect expression of heat stress tolerance of maize** - *to identify genes, component traits, and mechanisms of stress tolerance.*

2. **Identify and validate favourable genes/haplotypes** - *controlling adaptation of maize to heat stress in the tropical environments.*

3. **Implement rapid-cycle genomic selection** - *for generating open-source multi-parental synthetic populations and for further deriving heat stress resilience lines.*
4. Deploy heat stress resilient elite maize cultivars -
in the targeted agro-ecologies of South Asia through a regional alliance of public and private sector partners.

5. Strengthen capacity of alliance partners -
to sustainably serve climate change-vulnerable maize production system in the tropics.
Spring maize environment in South Asia

Mean temperature of 2000-2011

March
- Planting/Early seedling

April
- Late vegetative/Flowering

May
- Flowering/Grain-filling

June
- Late grain-filling/maturity

Temperature ranges:
- <30
- 30.1 - 35
- 35.1 - 38
- 38.1 - 40
- >40

Heat stress color codes:
Mean temperature of 2000-2011

Rainy-season (main) maize environment – Normal Year

June

July

August

September
Mean temperature of 2000-2011

Drought year → Warm-drought year
Projected changes in mean annual temperature (°C) in South Asia between 2000 and 2030

Kindie et al., 2014 (submitted)

• 1°C increase in temperature will require substantial (at least 10%) increases in irrigation in more than 28 m ha in arid and semi-arid regions of South and East Asia. (Erickson et al., 2011)
• Each degree day spent above 30°C reduced final yield by 1% under optimal/rain-fed conditions, & by 1.7% under drought conditions (Lobell et al., 2011)

• An increase in temperature of 2°C would result in a greater reduction in maize yields than a decrease in precipitation by 20% (Lobell and Burke, 2010)
Genetic enhancement for heat stress tolerance through integration of novels tools and techniques

- Genome-wide association study (GWAS)
- Rapid-cycle genomic selection (RCGS)
- High-throughput precision phenotyping
- Root phenotyping
- Lipidomics
- Double haploid (DH)
Advances in Genomics & Precision phenotyping: Redefining the maize breeding space!

- High density genotypes + High precision phenotypes

  - Powerful statistics
  - High efficiency computing

GWAS

- Robust “marker-trait associations” for trait of interest
- Reduced ‘environmental dependence’ (eg. Breeding for MSV resistance possible from Mexico!)
- Susceptible entries discarded even before planting (thanks to seed-DNA genotyping!)

GS

- Robust predictions enable resource efficient breeding! (less no. of yield evaluation plots)
- Enables speedier delivery of improved source populations
- “Open source” GS facilitates exchange of crucial information
Marker discovery using GWAS studies

Heat Tolerant Association Mapping (HTAM) panel

Panel constituted, involving 554 lines, including:

- CIMMYT-Asia: 343
- Selected lines from DTMA panel: 106
- MMRI, Pakistan: 52
- Purdue university: 23
- Vibha seeds: 20
- Kaveri seeds: 10
Marker discovery using GWAS studies

Heat Tolerant Association Mapping (HTAM) panel

- HTAM panel test–cross with two CIMMYT tester lines. one each from HG–A and B; Seed of CIMMYT testers shared with Seed company partners for generating TC seeds at their own location

- Trials involving over 1000 test–cross hybrids constituted for phenotyping under optimal temperature & managed heat stress:
  - Nine trials under optimal temperature regimes in India, Bangladesh & Nepal
  - Twelve trials under managed heat stress in India, Pakistan, Bangladesh & Nepal
Marker application using RC–GS approach

Four multi-parent synthetic (MPS) populations

- Already identified heat tolerant lines from CSISA–I
  - Two MPS populations (one each in HG–A and HG–B) developed
  - F2:3 families are being derived during current season.

- New heat tolerant promising lines during Spring–13 and USAID–Heat, Africa (HG–A lines: 11 and HG–B lines: 9)

  2nd inter-mating is being completed by April–14
### Donor lines for heat stress tolerance

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Tolerant lines (no stress injuries)

Tolerant lines (no stress injuries, except poor silk receptibility)

Highly susceptible lines
Drought tolerant lines under heat stress

Drought tolerance ≠ heat tolerance ≠ Drought + heat tolerance

Source: Jill, Zaidi et al. (Crop Science, 2013)
HTMA network for heat stress phenotyping and trials
Selection of Heat stress phenotyping site

Weather data and germplasm maturity:

- Last 10 years weather data (MaxT, MinT and RH/VPD)
- Maturity group (male flowering time) in terms of GDD

Planting heat stress phenotyping trials at a time, so that flowering and early grain filling stage is exposed to -

- Tmax > 35°C
- Tmin > 25°C
Heat stress phenotyping site

**Hot-Dry sites**

- Hyderabad, India
- Raichur, India

**Hot-Humid sites**

- Nepalgunj, Nepal
- Jessore, Bangladesh

Graphs show temperature (°C), relative humidity (RH (%)), and rainfall (mm) over time.
Vapour Pressure Deficit (VPD) under heat stress

Hyderabad         Jessor         Ludhiana         Raichur         Nepalgunj

Mean GY of trial  VPD-Late Veg  VPD-Reproductive
Tmax-Reproductive  Tmax-Late Veg

40°C
35°C

2.25 t/ha (0.33-6.54)
4.61 t/ha (0.47-7.81)
4.66 t/ha (1.33-6.78)
2.06 t/ha (0.61-5.09)
3.96 t/ha (0.89-5.66)

VPD (kPa)  Mean of the trial  t/ha

Phenotyping sites
Vapour Pressure Deficit (VPD) under heat stress

\[ y = -0.7422 \text{ Late-Veg} + 5.7626 \]
\[ R^2 = 0.8251^{**} \]

\[ y = -1.0055 \text{ Rep} + 6.1499 \]
\[ R^2 = 0.8963^{**} \]
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**Secondary traits associated with heat stress**
Heat-tolerant product pipe-line

Year-1

- **Rabi-12**: HT-line TC evaluated under heat stress
- **Spring-13**: HT-TC evaluated under heat stress
- **Kharif-13**: Seed increase of selected hybrids

**D-II crossing**
Lines with good *per se* & cross performance

**L x T cross**
Lines with good *per se* performance

Year-2

- **Spring-14**: Stage-2 hybrid evaluation for heat tolerance
- **Kharif-14**: Seed increase of top hybrids for On-farm trials

**HT and HTAM panel lines (except MMRI & Private sector)**
evaluation under heat stress

**HTAM panel constitution**

**HTAM panel TC**

**HTAM Test-cross phenotyping for heat tolerance**

**Stage-1 hybrid evaluation for heat tolerance**

**Stage-2 hybrid evaluation for heat tolerance**

Screening for common diseases & Seed increase of selected hybrids for Stage-2 evaluation
Heat tolerant commercial hybrids currently marketed by Pioneer and Monsanto, respectively.
Heat resilient hybrid deployment plan

- **IHT (5 Locations)**
  - 1000 - 1500 hybrids

- **AHT (10-15 Locations)**
  - 100-150 entries

- **MLT (20-25 Locations)**
  - 12-18 entries

- **Strip trials (50-60 locations)**
  - 4-6 entries

- **On Farm Demo (~500 sites)**
  - 2-4 hybrids

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Official launch

More sets (using molecular tools), with further enhanced heat tolerance

- **1st Set**

- **2nd & 3rd Set**
Capacity building...


