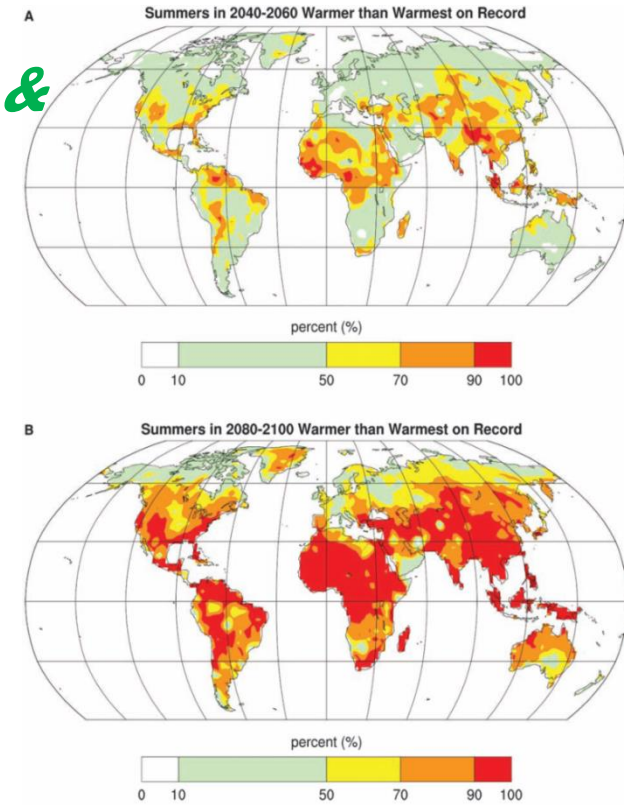
Heat Stress Tolerant Maize for Asia (HTMA)

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

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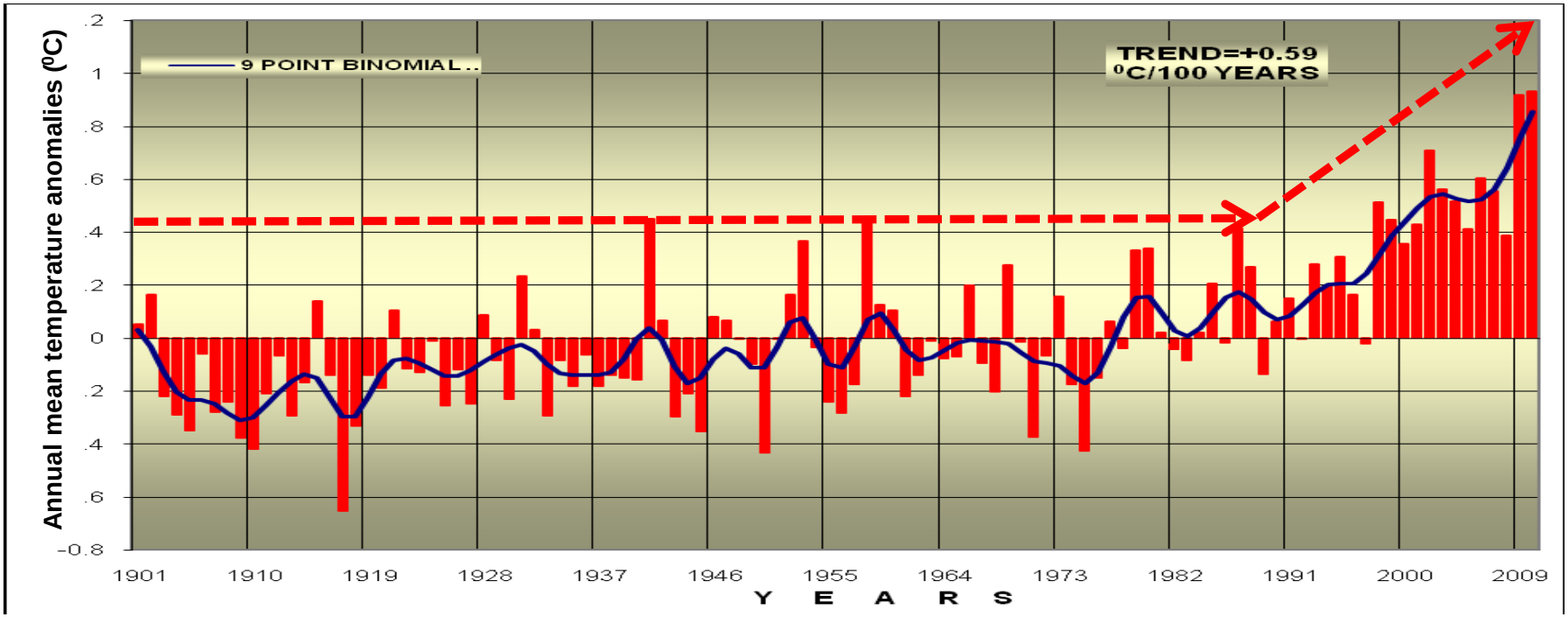
Climate change effects in India

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)

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International Maize and Wheat Improvement Center

informa
No. 1829 • 01-08 February, 2013

New project launched: Heat Stress Tolerant Maize for Asia

South Asian farm lands 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.

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HTMA
Specific Objectives:

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.

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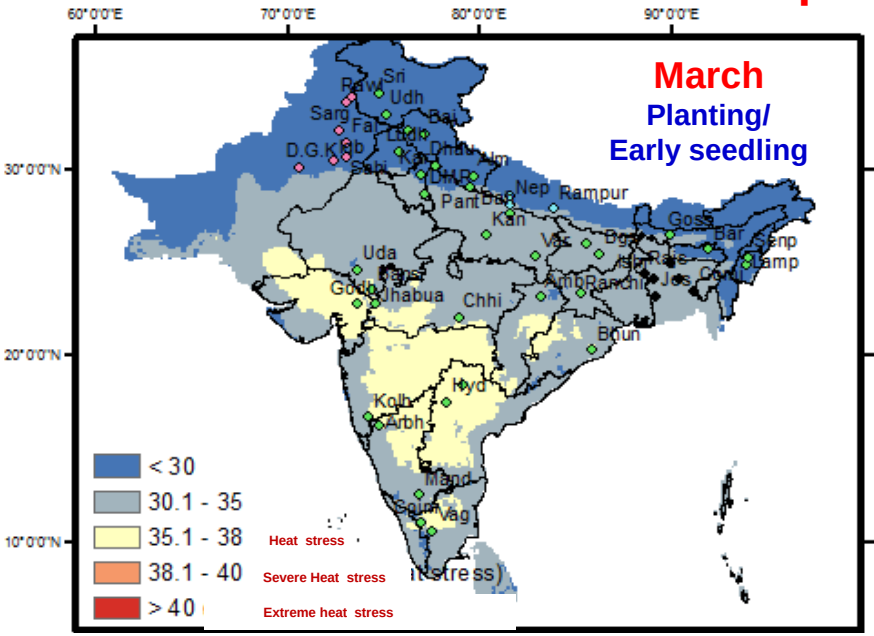
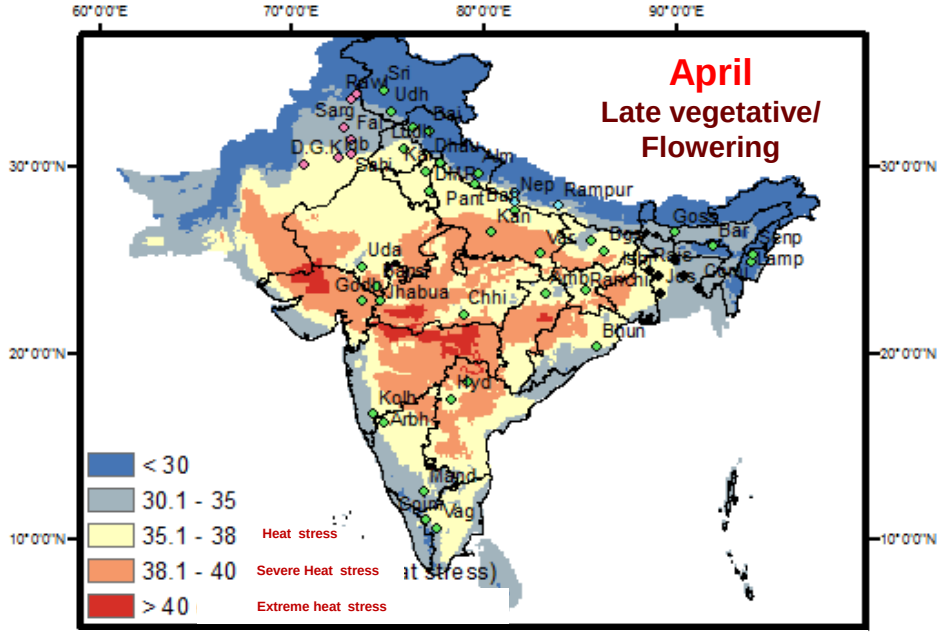
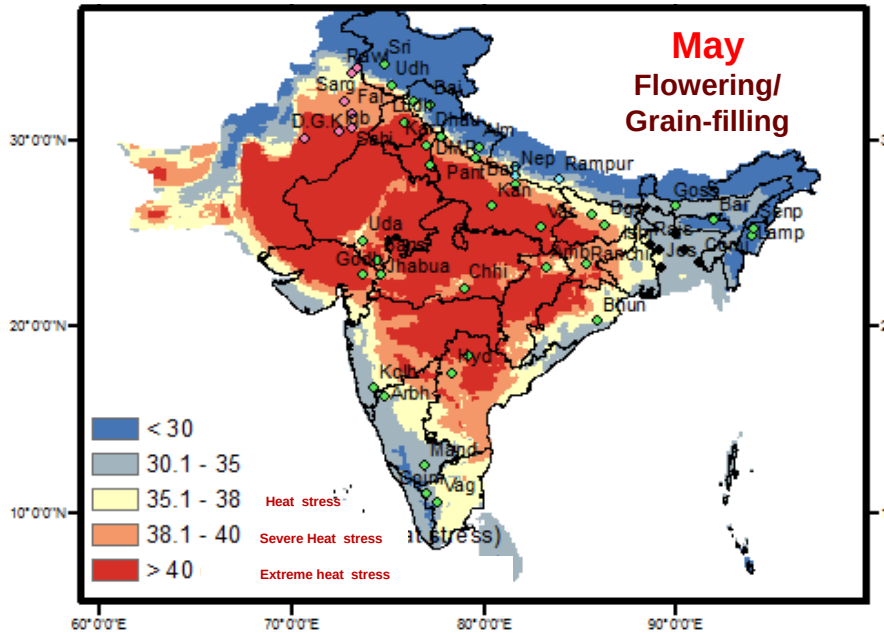
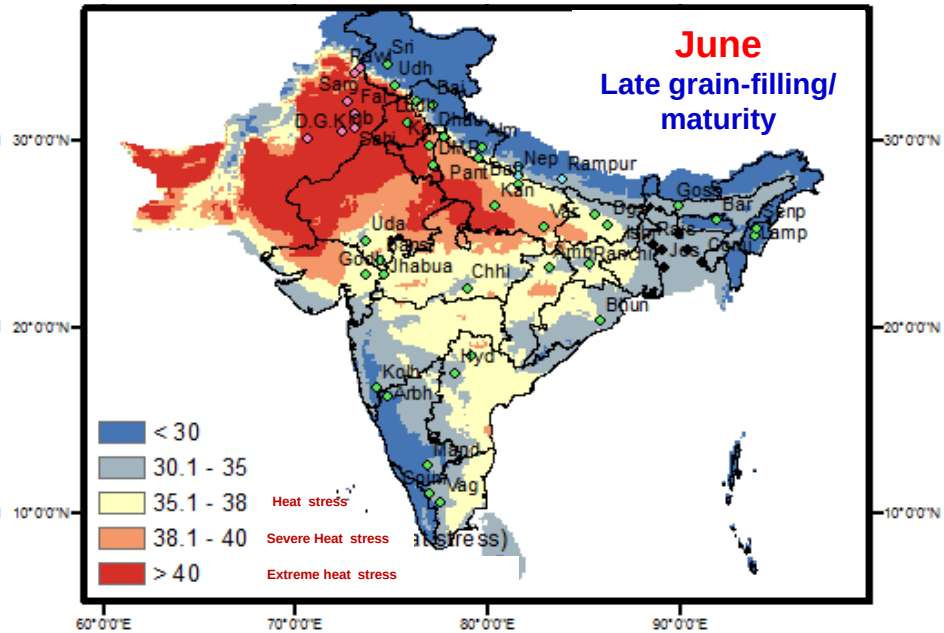
Mean temperature of 2000-2011



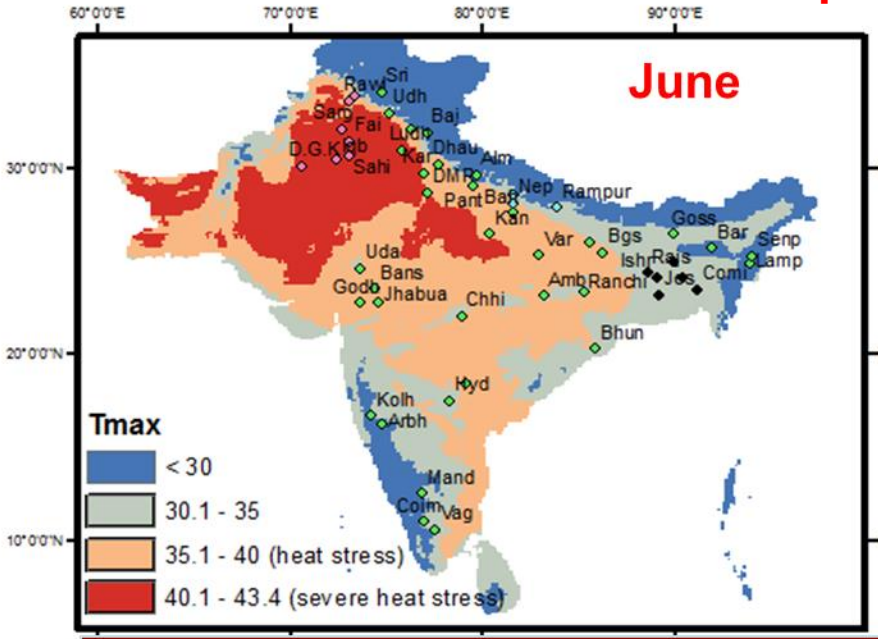


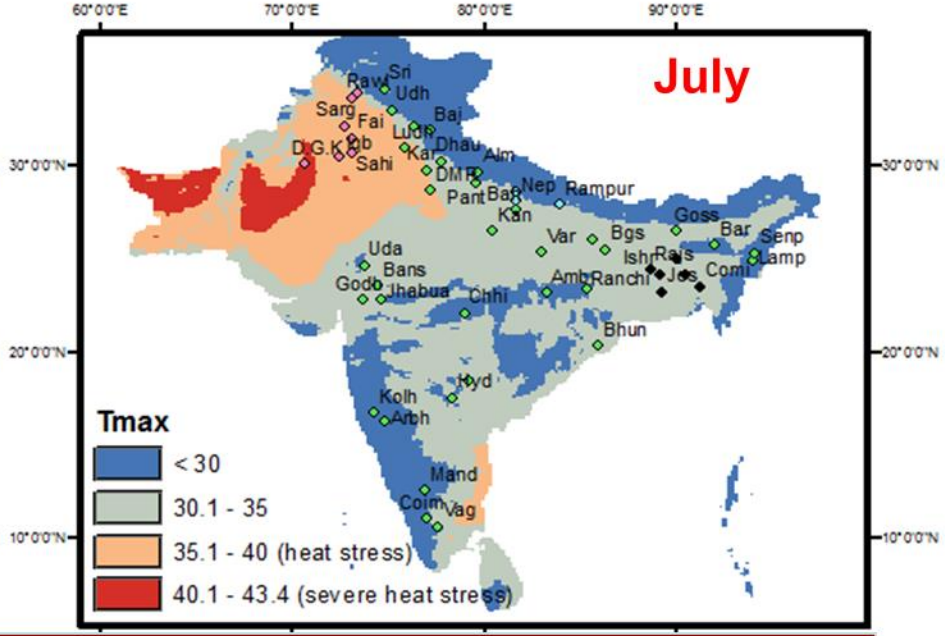
Spring maize environment in South Asia



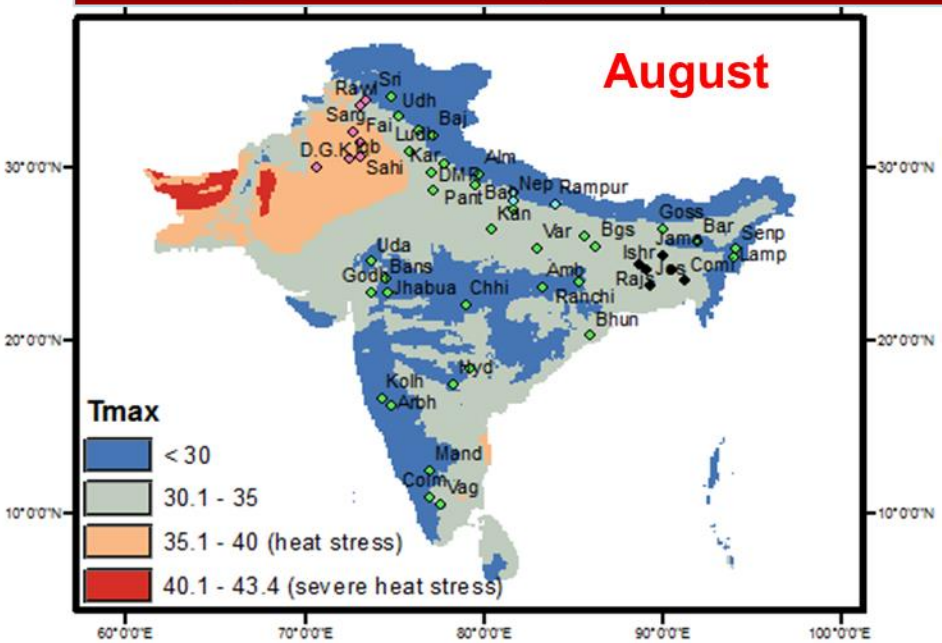


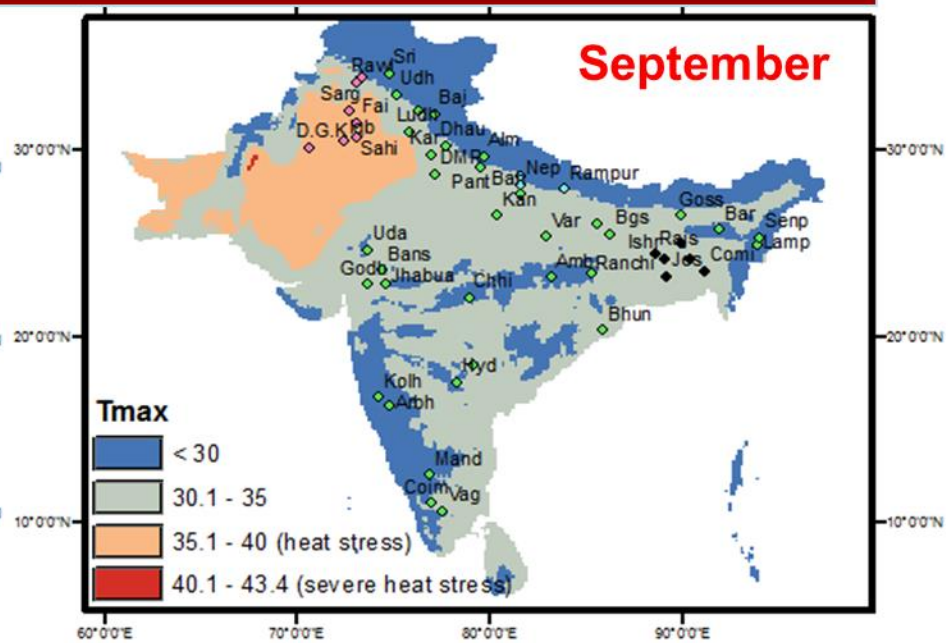
Mean temperature of 2000-2011



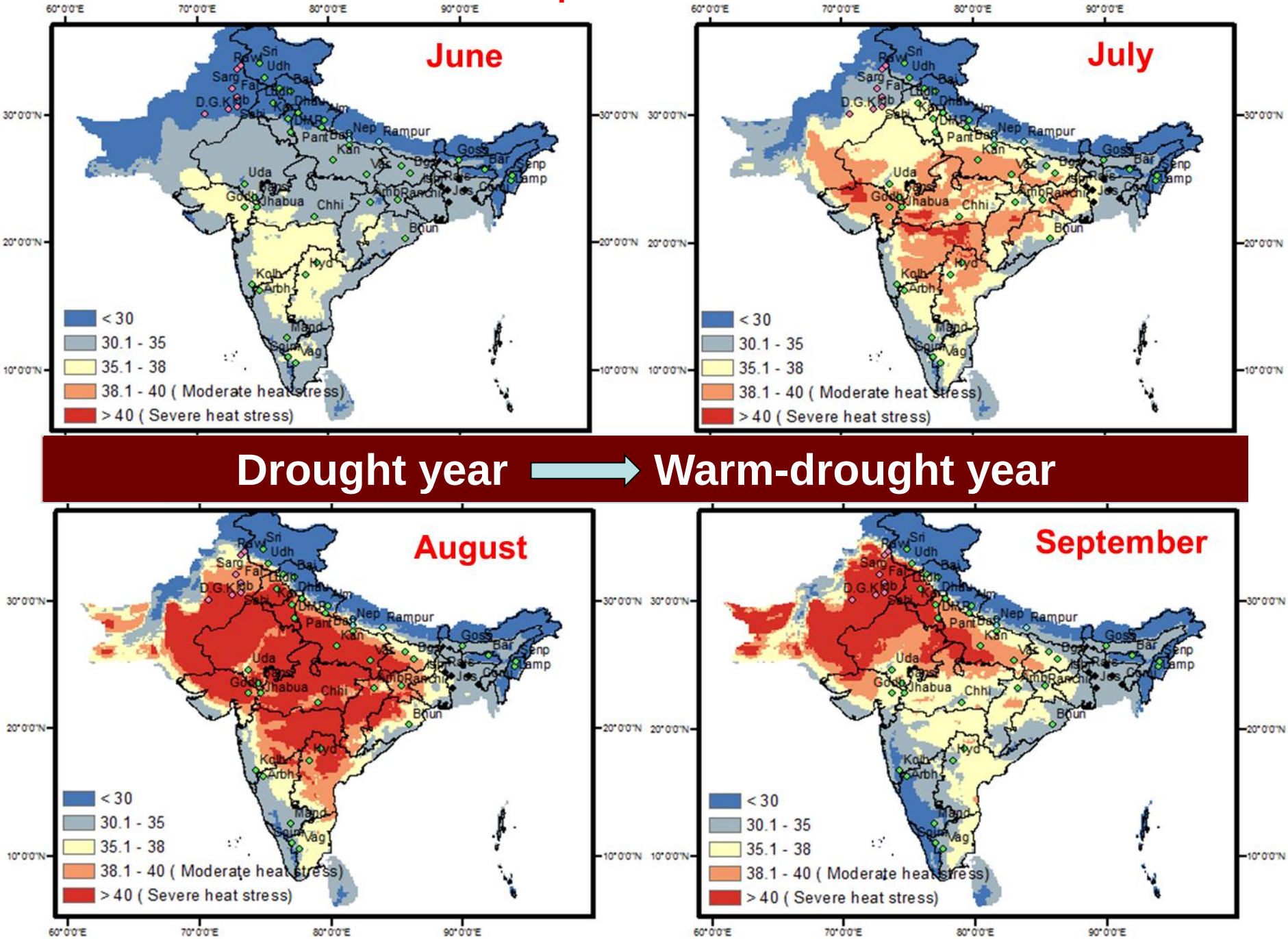


Rainy-season (*main*) maize environment – Normal Year

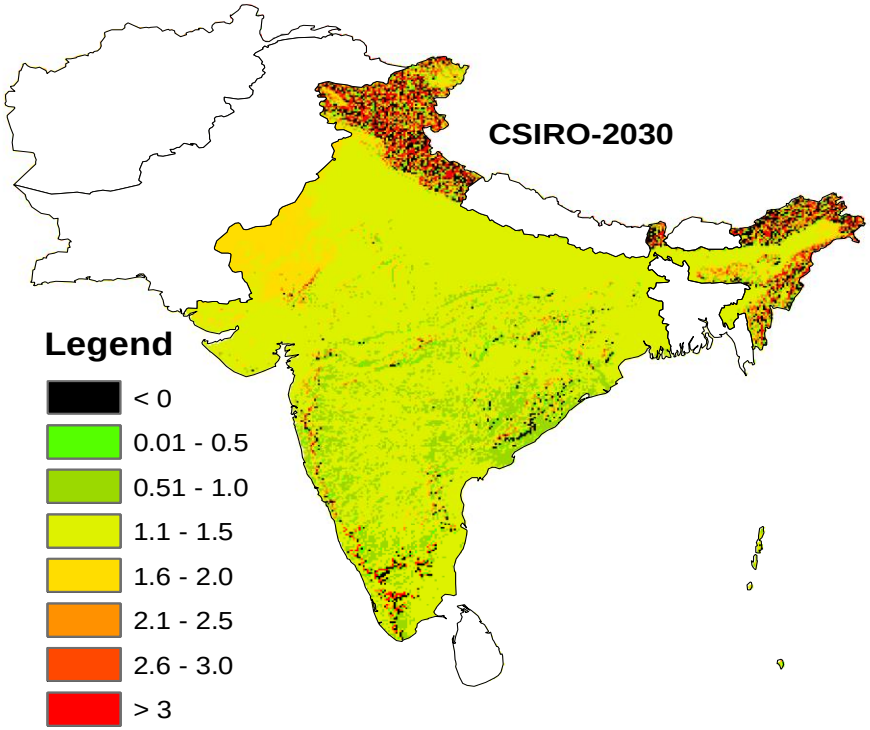


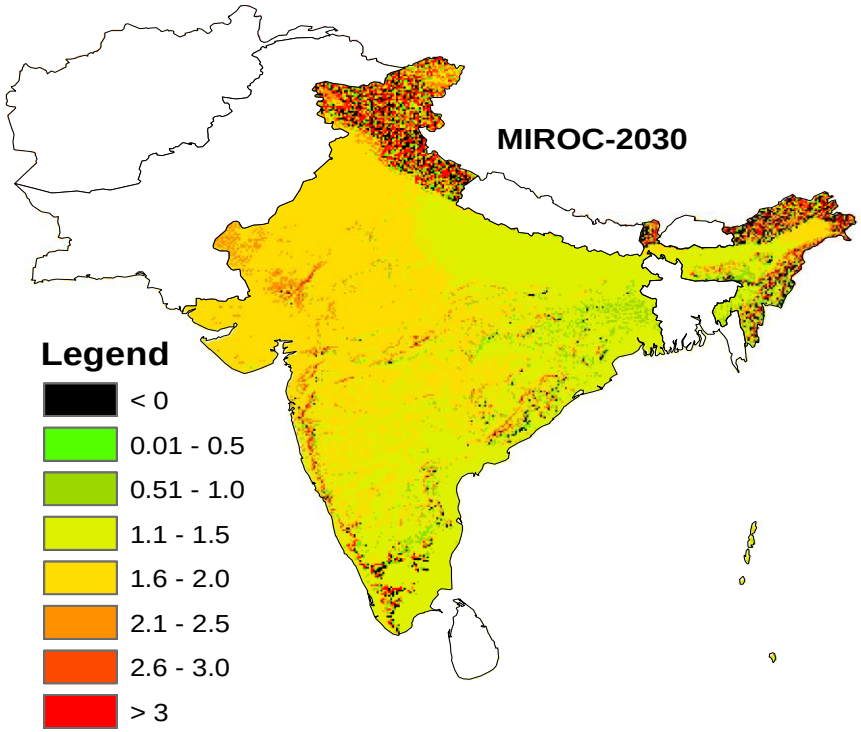


Mean temperature of 2000-2011



Projected changes in mean annual temperature (º C) in South Asia between 2000 and 2030

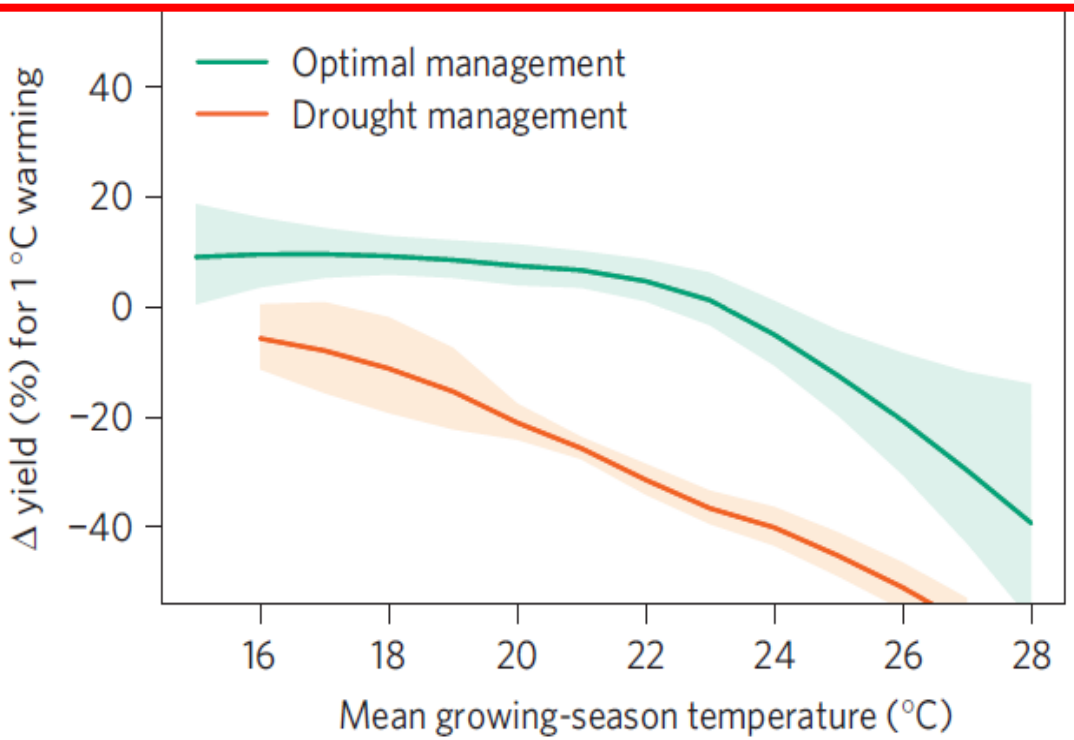




Kindie *et al*., 2014 (submitted)

- 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)

Susceptibility to heat stress



- Each degree day spent above 30ºC 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)

Heat Stress Tolerant Maize for Asia (HTMA)

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)

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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**

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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**

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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

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Donor lines for heat stress tolerance

Entry	Name	GrainYield GW	Anth Date	ASI	Ears/ Plant	Leaf Firing	Tassel Blast	Tassel Sterility
		t/ha	d	d	#	%	%	0-1
Tolerant lines (no stress injuries)								
54	ZL11271	1.88	51.6	1.5	0.69	0.0	0.0	0.0
55	VL0512420	1.95	53.9	-2.0	0.90	2.1	5.0	0.0
58	VL1018161	1.89	54.7	5.3	0.46	0.0	2.0	0.5
81	VL1013294	1.39	55.3	-1.7	0.98	0.0	0.0	0.1
86	VL109084	1.36	55.1	-3.8	0.65	1.1	3.0	0.0
19	VL1012835	1.26	58.4	0.5	0.81	0.0	0.0	0.0
48	ZL111008	1.23	53.4	1.9	0.86	0.0	0.0	0.0
50	ZL11376	1.22	57.4	0.4	0.69	0.0	0.0	0.0
Tolerant lines (no stress injuries, except poor silk receptibility)								
83	ZL111040	1.04	55.5	3.4	1.52	0.0	0.0	0.0
85	VL1018793	1.03	55.6	3.6	0.85	0.0	0.0	0.0
87	VL108496	1.03	55.3	1.6	0.89	0.0	0.0	0.0
36	VL107657	1.02	58.8	0.5	1.62	0.0	0.0	0.0
160	VL0512386	1.02	62.4	1.0	0.94	0.0	0.0	0.0
130	VL1017538	1.01	60.3	0.8	1.36	0.0	0.0	0.0
Highly susceptible lines								
111	VL1032	-0.01		16.8	0.00	76.6	94.5	0.0
104	VL1029	0.00		17.1	0.01	21.4	95.0	0.1
113	VL1033	0.01		16.7	0.12	58.7	98.3	0.0
103	VL108769	0.03		17.3	0.14	91.2	100.0	0.1
4	VL106	0.00		17.1	0.00	96.2	100.0	0.1
Mean		**0.03**	**57.6**	**10.2**	**0.95**	**11.7**	**17.5**	**0.3**
p		ns	ns	***	***	***	***	***
Heritability		**0.89**	**0.87**	**0.77**	**0.46**	**0.95**	**0.95**	

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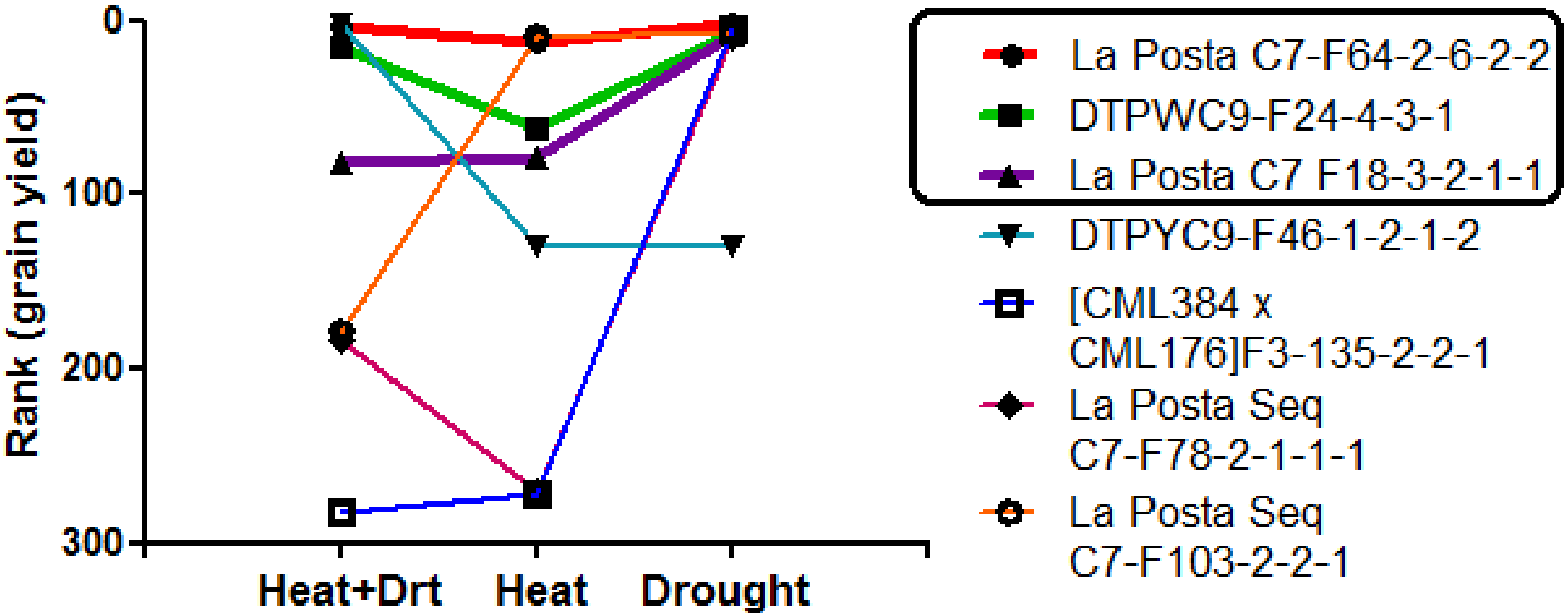
CSISA-phase I

Drought tolerant lines under heat stress



Drought tolerance ≠ heat tolerance ≠ Drought + heat tolerance

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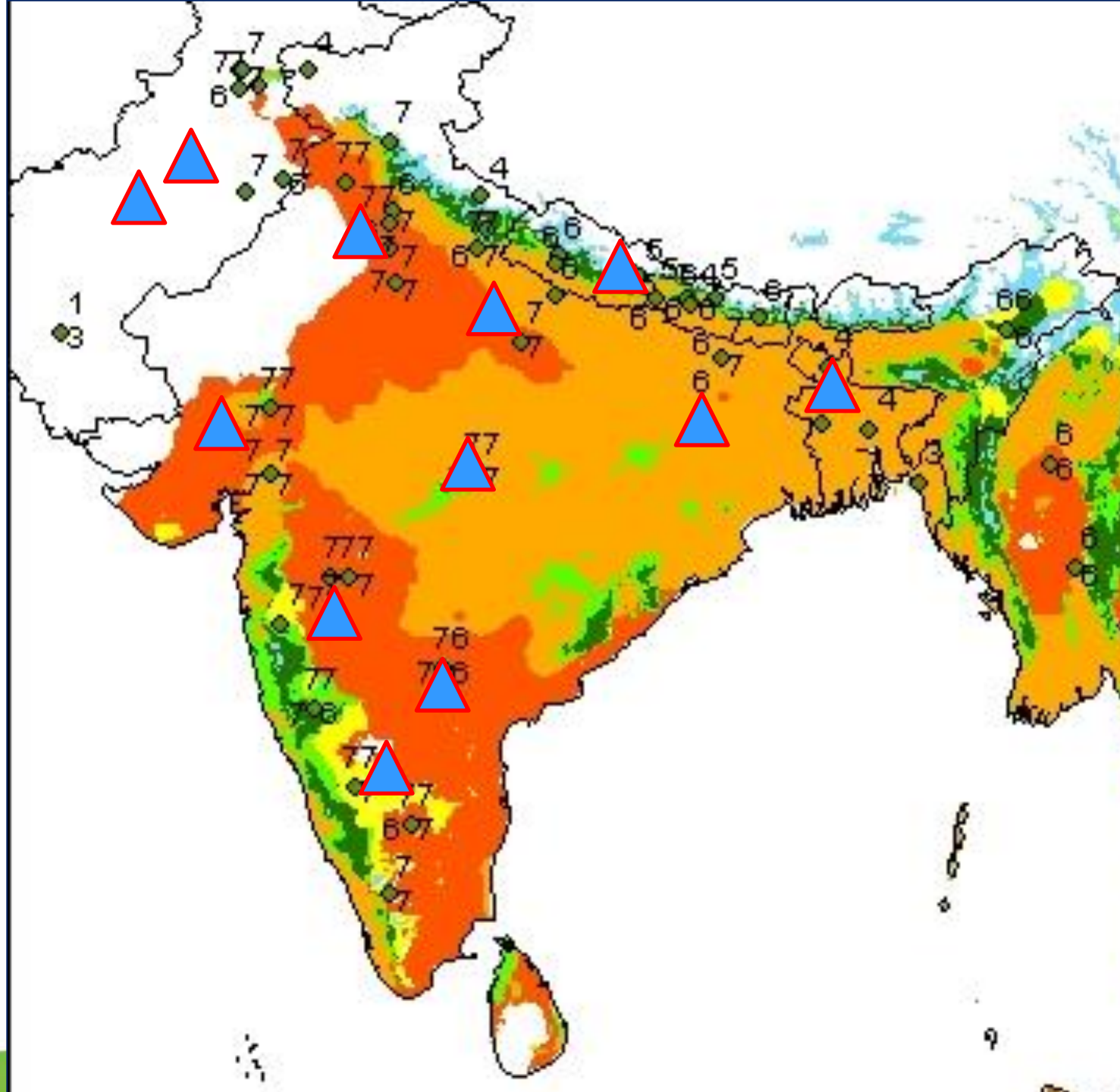
Source: Jill, Zaidi *et al*. (Crop Science, 2013)

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 > 35^0C**
  - **Tmin > 25^0C**

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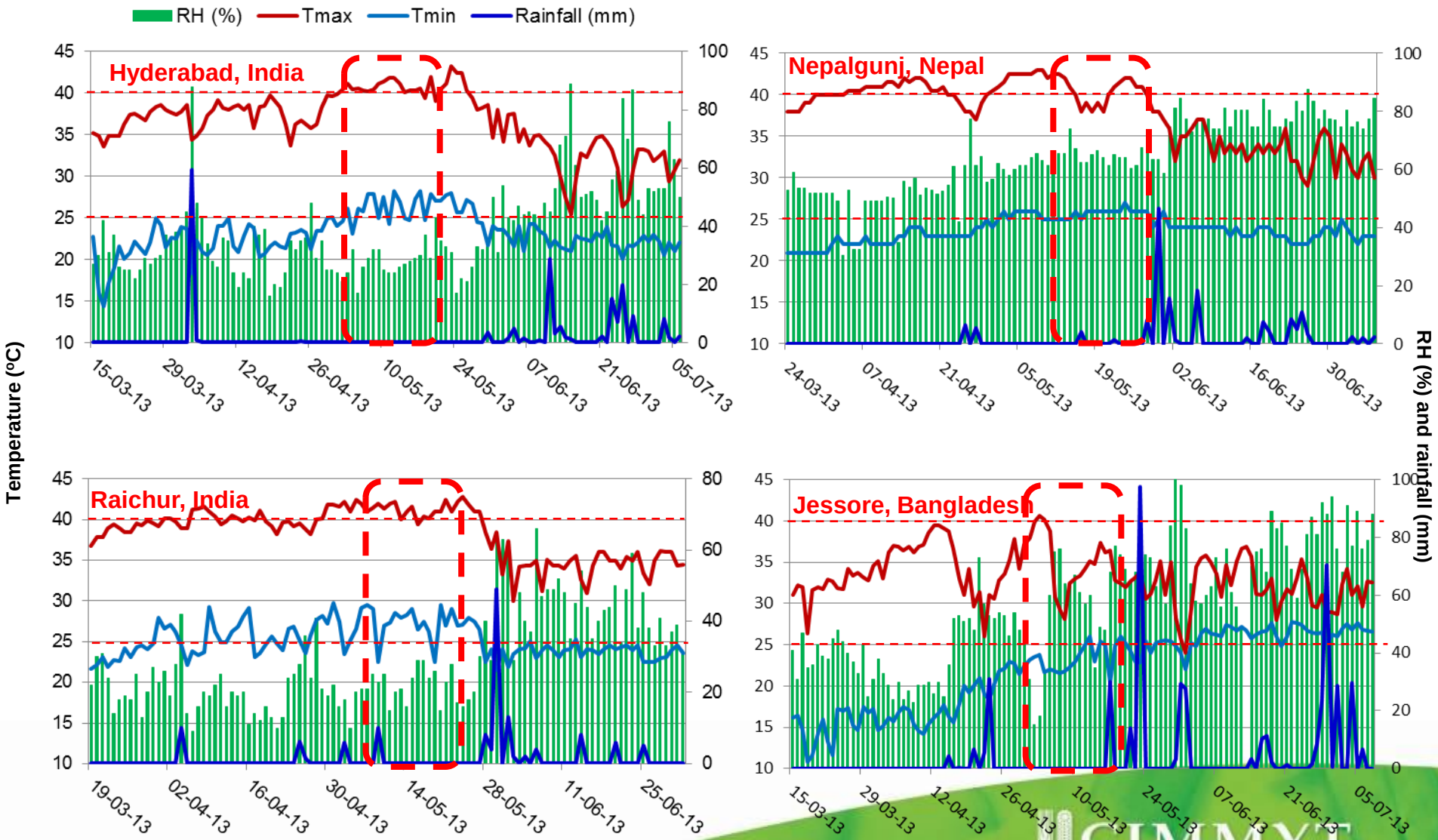
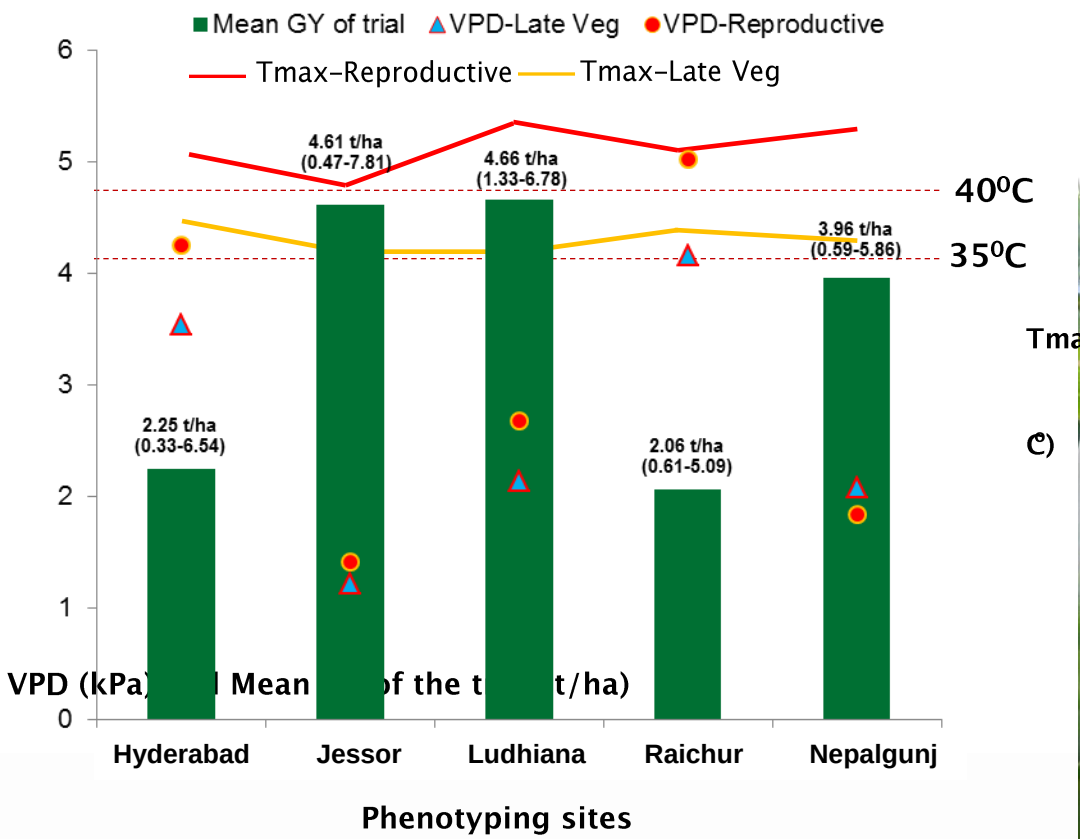
Heat stress phenotyping site……..



Hot-Dry sites

Hot-Humid sites

Vapour Pressure Deficit (VPD) under heat stress



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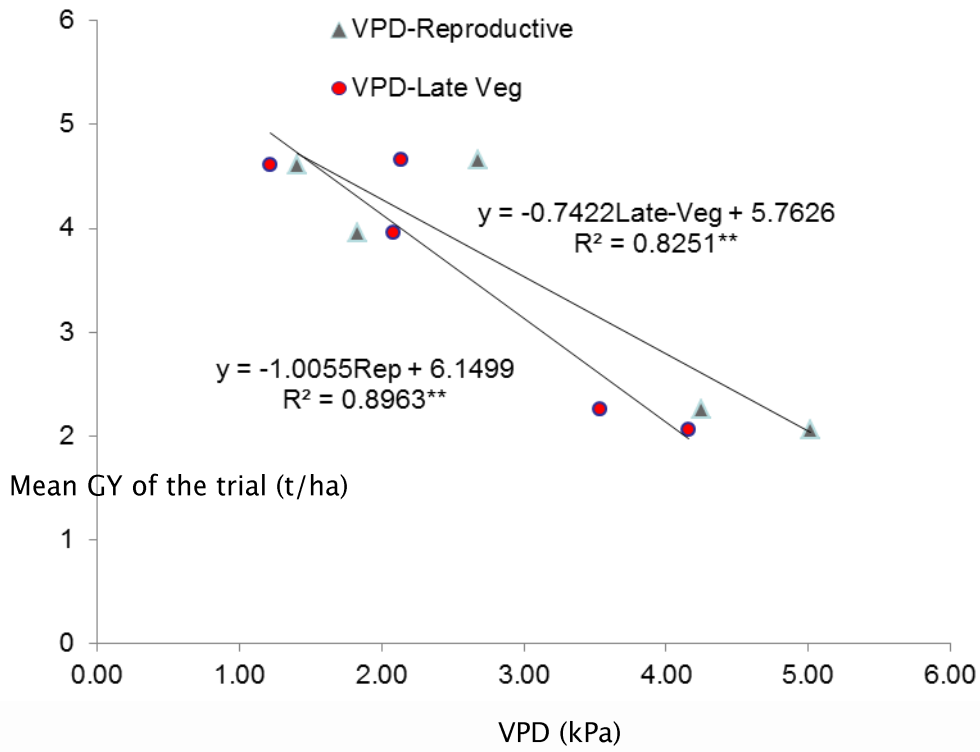
Vapour Pressure Deficit (VPD) under heat stress



Secondary traits associated with heat stress

Leaf firing

Tassel blast

Anthesis-silking interval

Pollen shedding duration

Ear per plant

Grain yield

Pollen viability

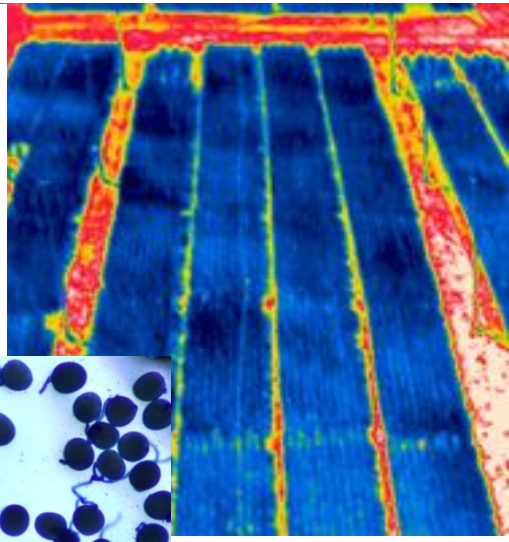
Silk receptibility

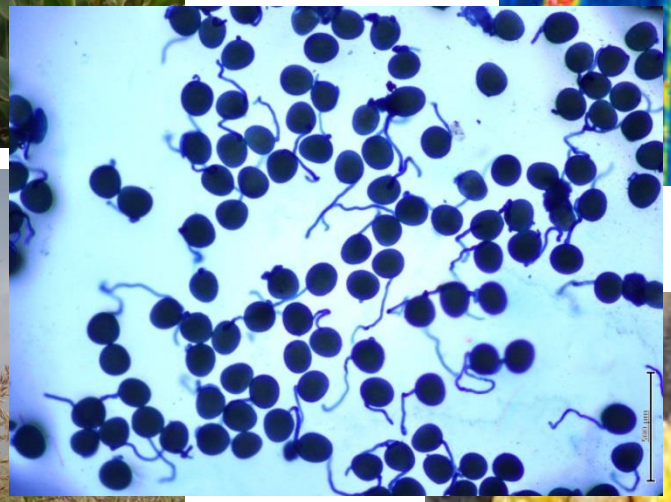
Canopy temperature

Chlorophyll content

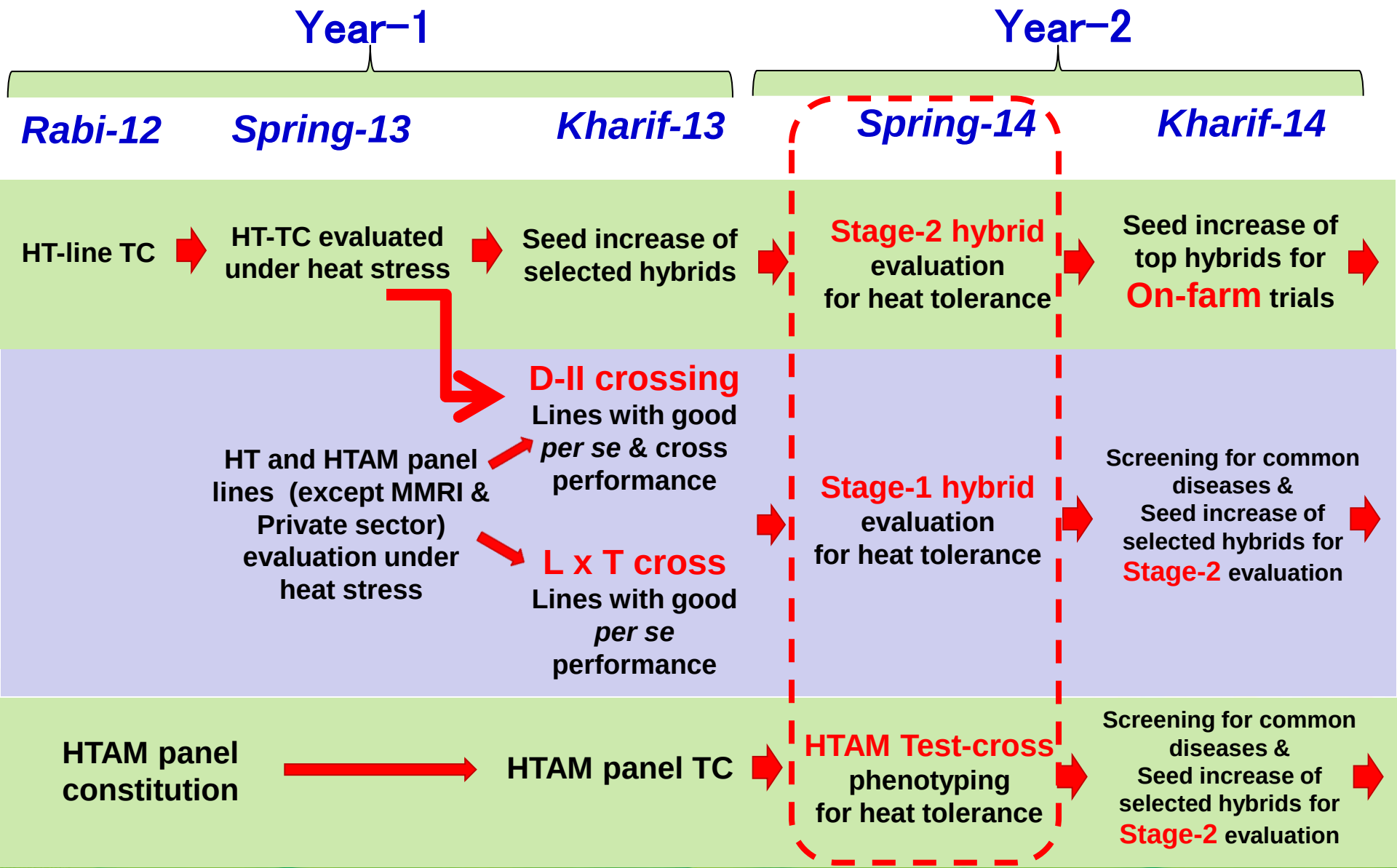
Canopy temperature

Lipid profiling

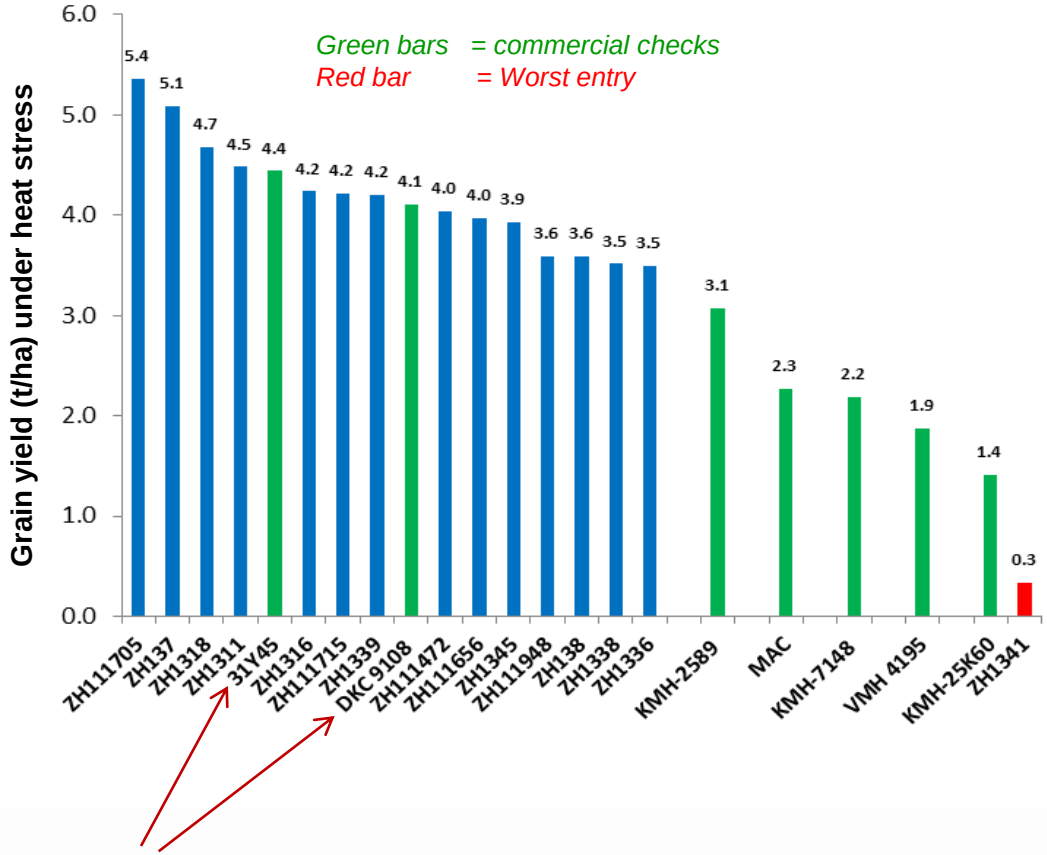




Heat-tolerant product pipe-line .....

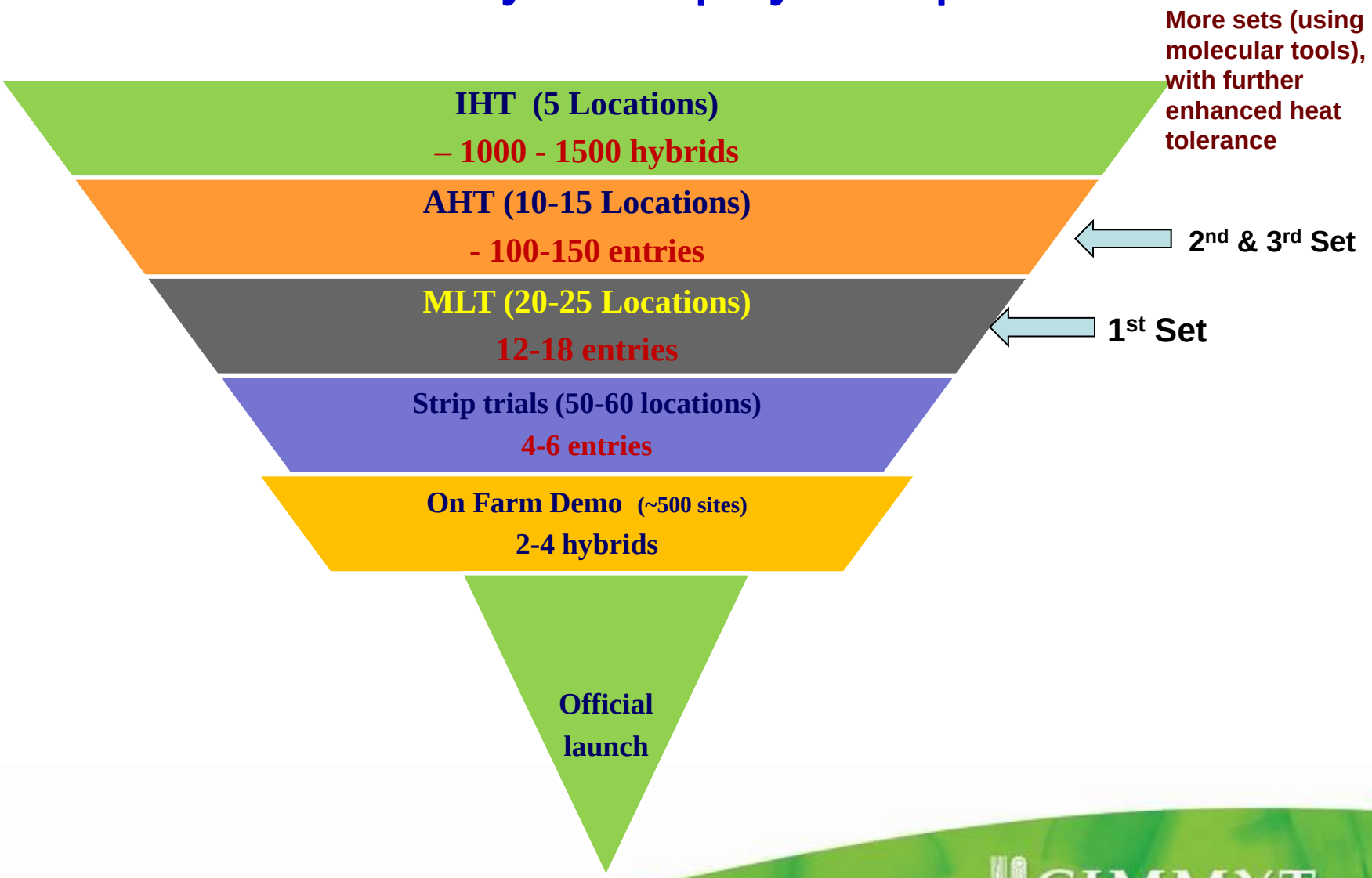


1st set of heat tolerant hybrids



Heat tolerant commercial hybrids currently marketed by Pioneer and Monsanto, respectively

Heat resilient hybrid deployment plan



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Capacity building…

- Workshop on '*Genomic selection in maize*', 23 Jan, 2013 at CIMMYT-Hyderabad.
- Training on '*Precision phenotyping & data management*', 1 – 7 May, 2013 at CIMMYT-Hyderabad.
- In-country training on '*Precision phenotyping for heat stress tolerance in maize*', 16 Jan, 2014 at NMRP, Rampur.


Thanks!