The Promise of Drought Tolerant Seed Technologies

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International Maize and Wheat Improvement Center (CIMMYT)

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Drought Tolerant Maize-Index Insurance Pilot Project Meeting, Nairobi

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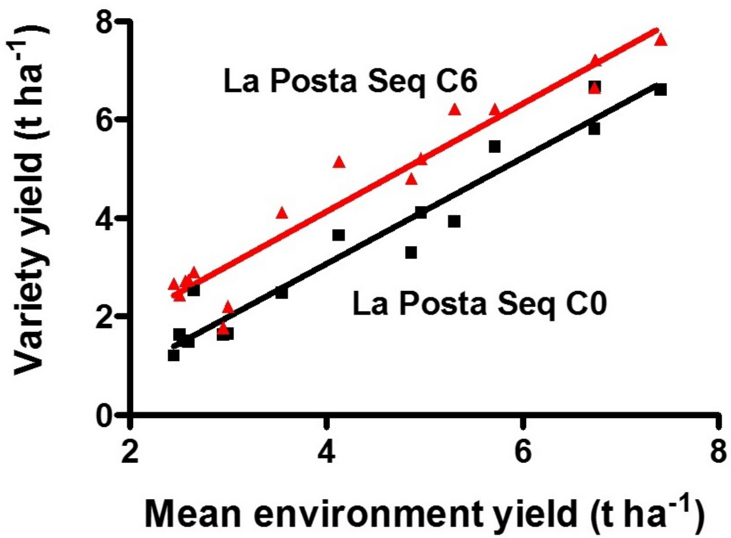
CIMMYT's success in breeding drought tolerant maize germplasm has four decades of continuous efforts….

Population	Description	Genetic material
DTP-Y and DTP-W	60% lowland tropical, 20% subtropical, 20% temperate	Derived from 25 putative drought tolerance sources (Tuxpeño Sequia, Latente, Michoacan21, Suwan 1, CIMMYT Pops. 22, 32, 62, 64,and 66); 11% landraces; rest from elite drought tolerant sources, Corn Belt hybrids, germplasm from Thailand and S. Africa
La Posta Sequia (LPS)	Lowland tropical, late-maturing, white dent.	Derived from CIMMYT Population 43 C, SR.



Drought and NUE maize germplasm development via recurrent selection was initiated at CIMMYT in 1975.

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Breeding for drought tolerance at CIMMYT is nearly four decades old…

- Well-constituted pools and populations (e.g., La Posta Sequia, DTPY, DTPW) with intensive recurrent selection under drought stress
- Managed stress screening network
- Well-defined phenotyping protocols and selection criteria (e.g., Anthesis-silking interval)

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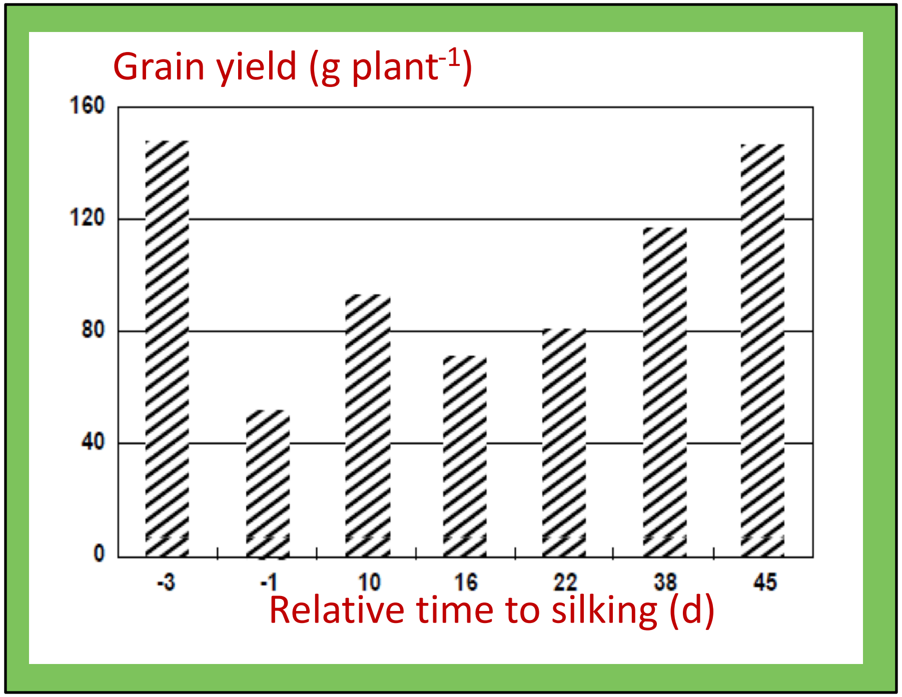
Stage-sensitivity for Drought in Maize

- All the growth stages in maize are, in general, vulnerable to drought.
- High vulnerability at germination and seedling establishment stages (but least genotypic variability) = NOT a breeding target.
- **High susceptibility at flowering followed by grain filling stage; sufficient genetic variation = Breeding target.**
- The most critical period **– one week before to three weeks after silk emergence**



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Stage-sensitivity for Drought in Maize

Growth stage	Susceptibility of yield to drought	Probability of stress	Probability of breeding success
Germination, establishment	High	Usually high	Low
Pre-flowering	Low	Depending on the environment	Medium
Flowering	High	Depending on the environment	High
Post-flowering	Medium	Usually high	Medium

The aim of managed drought is not to simulate a farmers field, but create a screen that has high probability of occurrence in farmers' fields and clearly reveals genotypic differences under stress.

Apply so much stress that yield is reduced by at least 50% (better 65-75 %) of the unstressed screening at that site
=> Genotype-by-stress interactions become visible

Defining Drought Stress

- Stage of drought stress: Vegetative; Flowering; Grain filling
- Type of drought stress: Mild, Moderate, Severe
- Interaction with other factors: Heat; Low soil N

Balance of optimum, managed drought stress locations (on-station trials) and natural stress conditions (on-farm trials) important for success in breeding DT maize

Defining Drought Tolerance

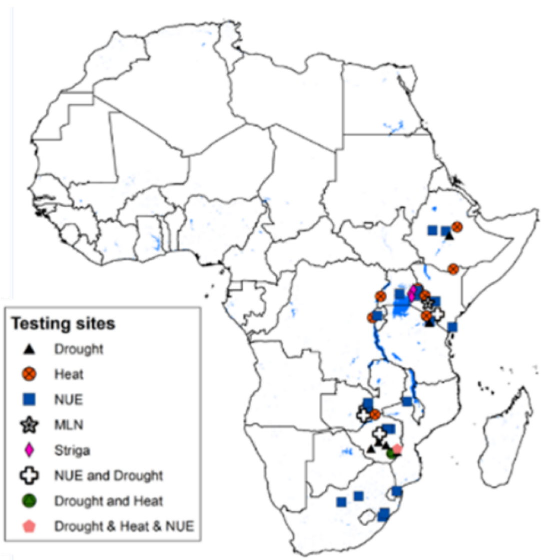
In case of maize (as per CIMMYT), “drought tolerance” is the ability of a genotype to show a **substantive and statistically significant yield advantage over the widely grown commercial checks** (tested in several drought stress locations), and often under severe drought conditions, including flowering and grain filling period.

Pillars to increase phenotyping accuracy and efficiency

Network

Protocols

Data collection methods



updated from Prasanna et al. 2013

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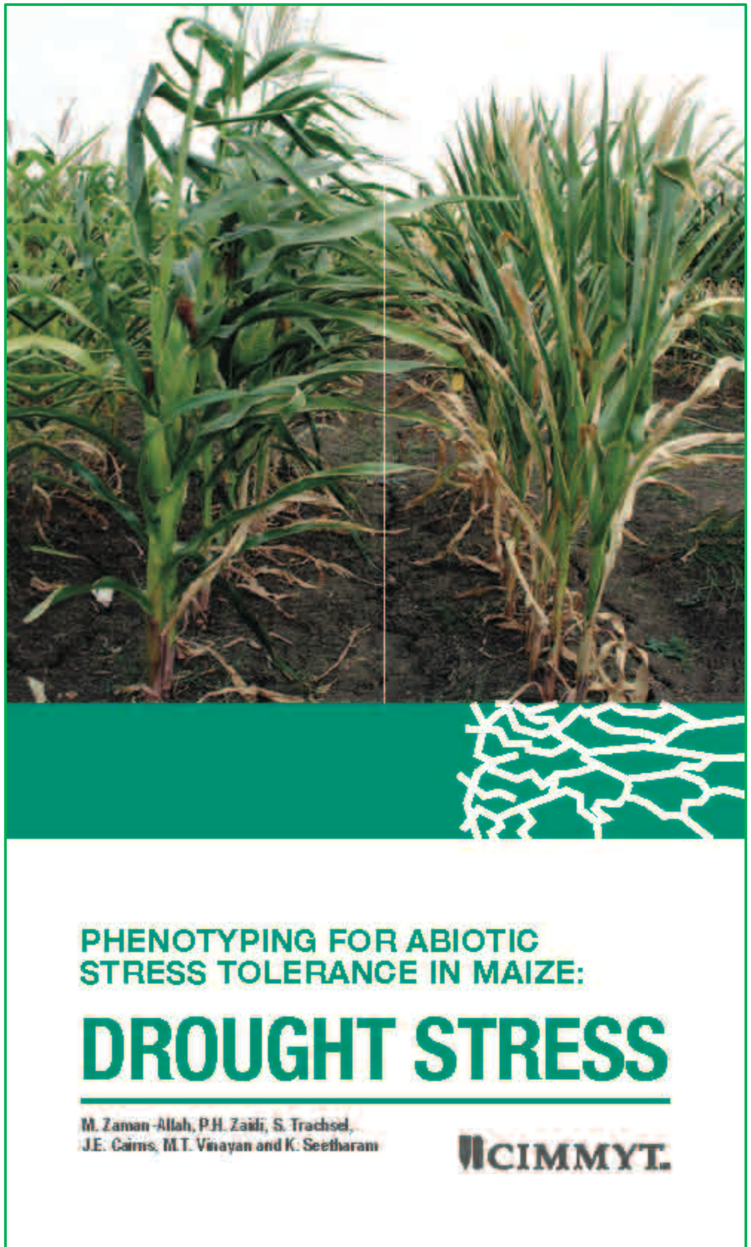
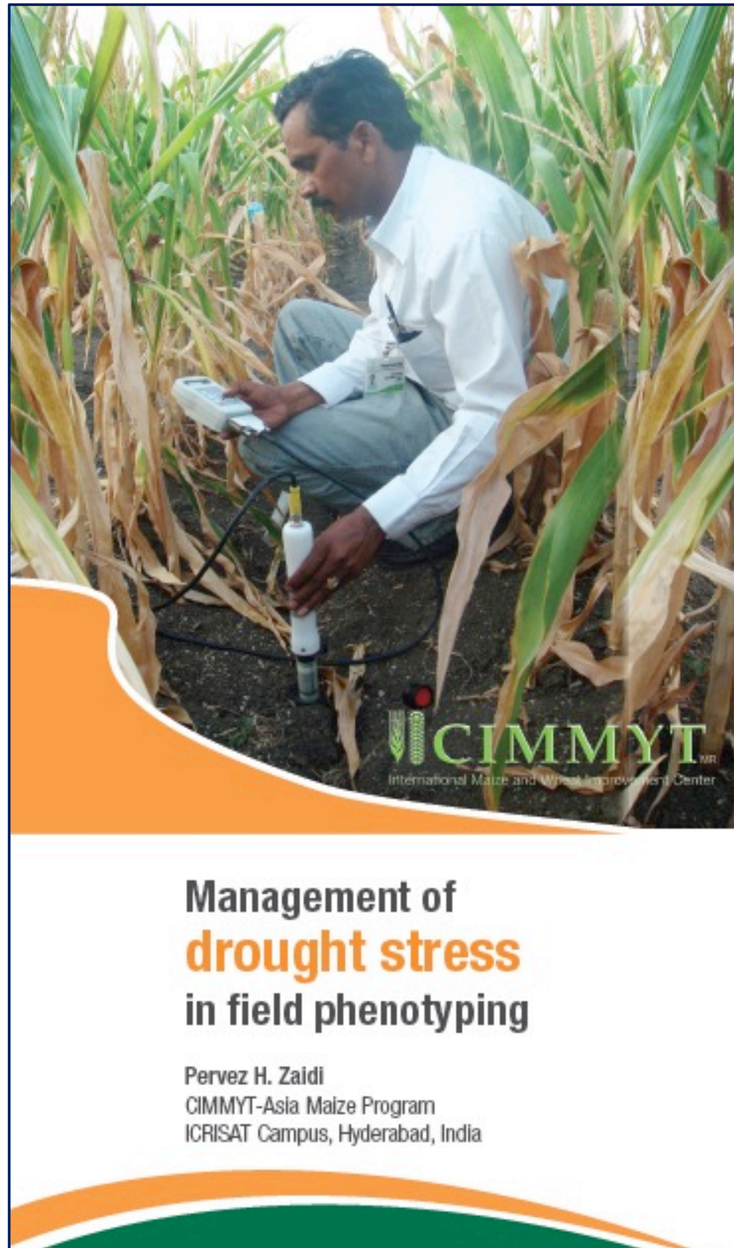
Harmonized Phenotyping Protocols





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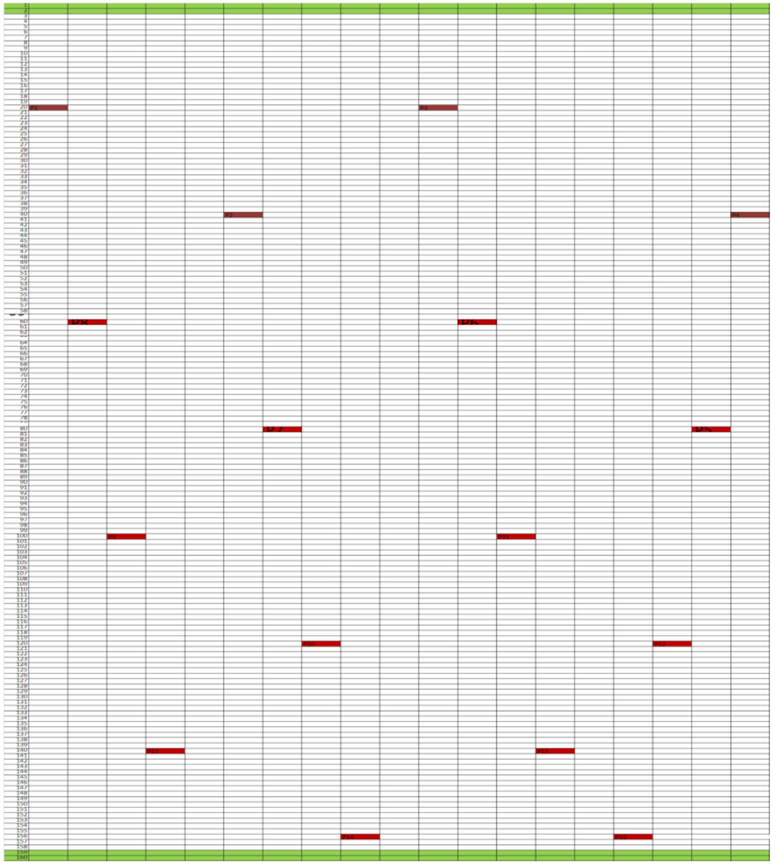
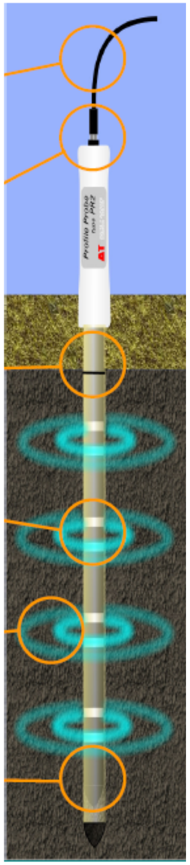
Drought Stress Imposition by Monitoring the Soil Moisture Content in Dedicated Field Blocks





Operation	Date	Day/Week	Tmax	Tmin	GDD
2011-12					
Planting	01-Dec	1	30.9	14.3	12.6
	07-Dec	Week-1	30.2	12.8	84.7
	14-Dec	Week-2	28.8	11.2	169
	21-Dec	Week-3	29.6	10.5	239.8
	28-Dec	Week-4	29.5	10.7	306.2
	04-Dec	Week-5	31.3	18.8	401.1
	11-Jan	Week-6	27.8	15.1	502.5
Last irrigation	**18-Jan**	49	**25.4**	**10.2**	556.4
2014-15					
Planting	30-Nov	1	29.9	14.1	11.6
	06-Dec	Week-1	30.2	12.8	82.3
	13-Dec	Week-2	26.4	10.3	157.4
	30-Dec	Week-3	30.2	11.2	212.4
	27-Dec	Week-4	28.2	9.4	276.0
	03-Jan	Week-5	28.2	10.1	345.2
	10-Jan	Week-6	26.3	8.3	405.4
	17-Jan	Week-7	27.3	8.4	469.3
Last irrigation	**22-Jan**	54	**27.2**	**9.8**	554.0

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CIMMYT's Breeding Strategies for Improving Drought Tolerance in Maize

1. Indirect selection under favourable environments
2. Direct selection under stress environments
3. Selection for physiological and morphological traits

- Grain yield => increase
- Ears per plant => increase
- Anthesis-silking interval (ASI) => decrease
- Leaf senescence => decrease
- Leaf rolling => decrease
- Tassel size => decrease

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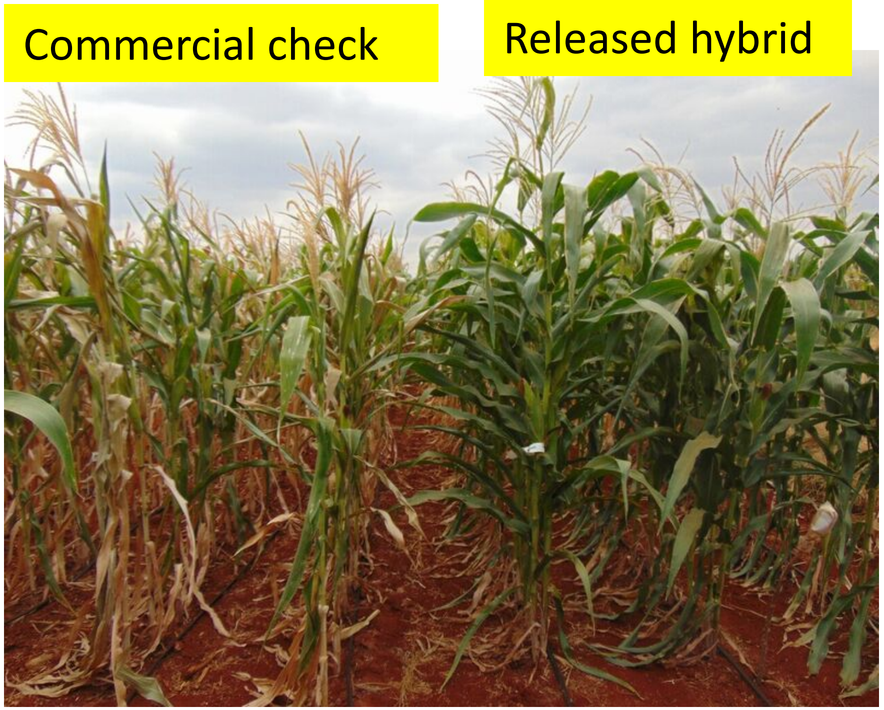
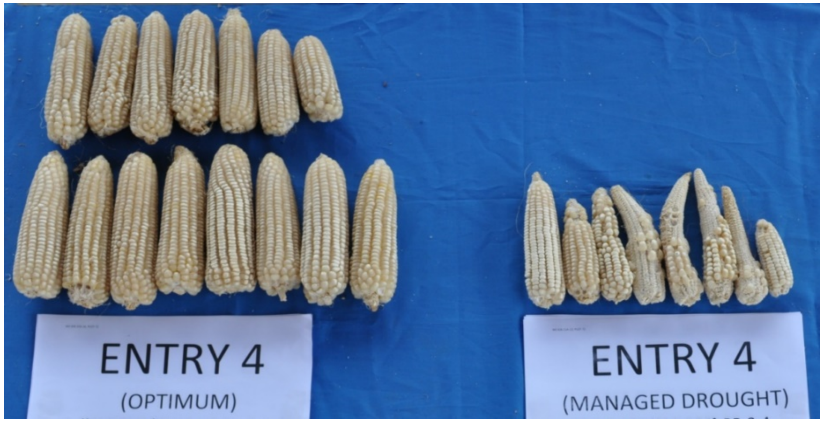
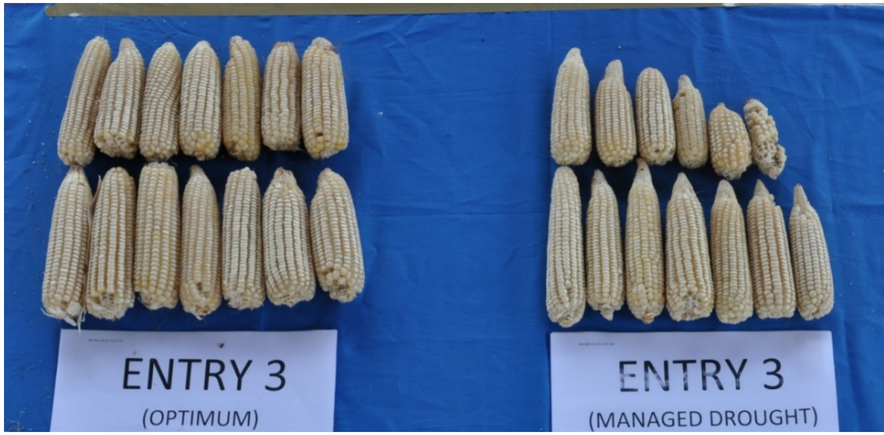
Drought tolerant and susceptible hybrids under managed drought stress at Kiboko, Kenya







Several high-yielding and DT DH lines developed by CIMMYT Maize Breeding Program

DT vs. Commercial Drought-vulnerable Hybrids (Malawi; 2015)

MH28, a DT hybrid

Commercial drought-susceptible hybrids

Source: Peter Setimela (CIMMYT)

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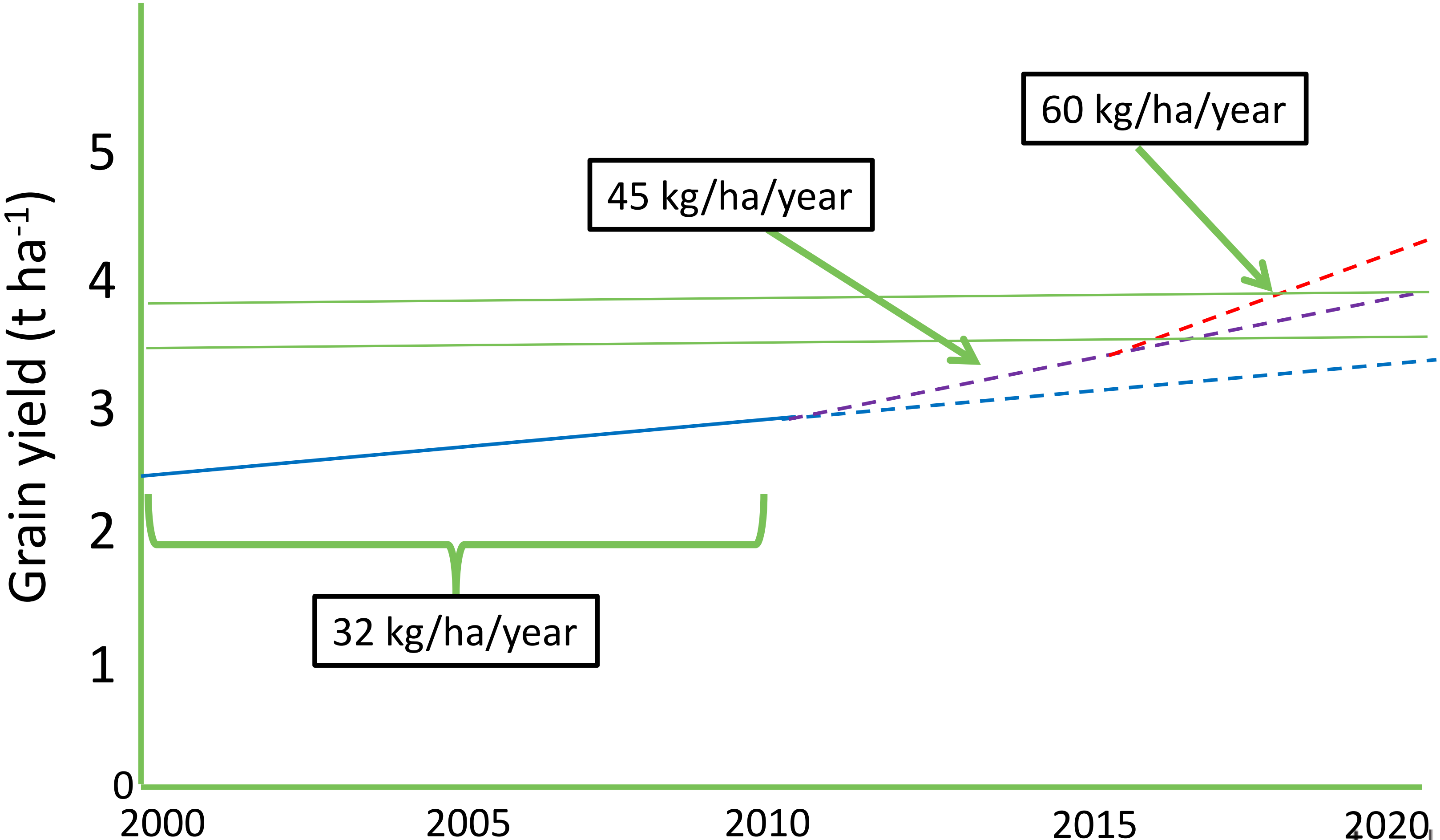
Driving Genetic Gain under Drought-prone Environments



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Drought Tolerant Maize in Sub-Saharan Africa

- **DT maize varieties,** developed by CIMMYT and IITA, released across 20 countries in sub-Saharan Africa, grown on nearly **3.5 M ha.**
- Partnerships with **over 100 SME seed companies** in producing and commercializing annually **~85,000 tons** of certified DT maize seed across Africa.

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How did CIMMYT-derived Hybrids perform during the El Nino-induced drought and heat in southern Africa (2015-16)

CIMMYT-derived varieties **yielded almost double** than the most popular commercial variety (SC513)

1.5 Mg ha^{-1} compared to 2.9 Mg ha^{-1}

Source: Setimela et al. 2017

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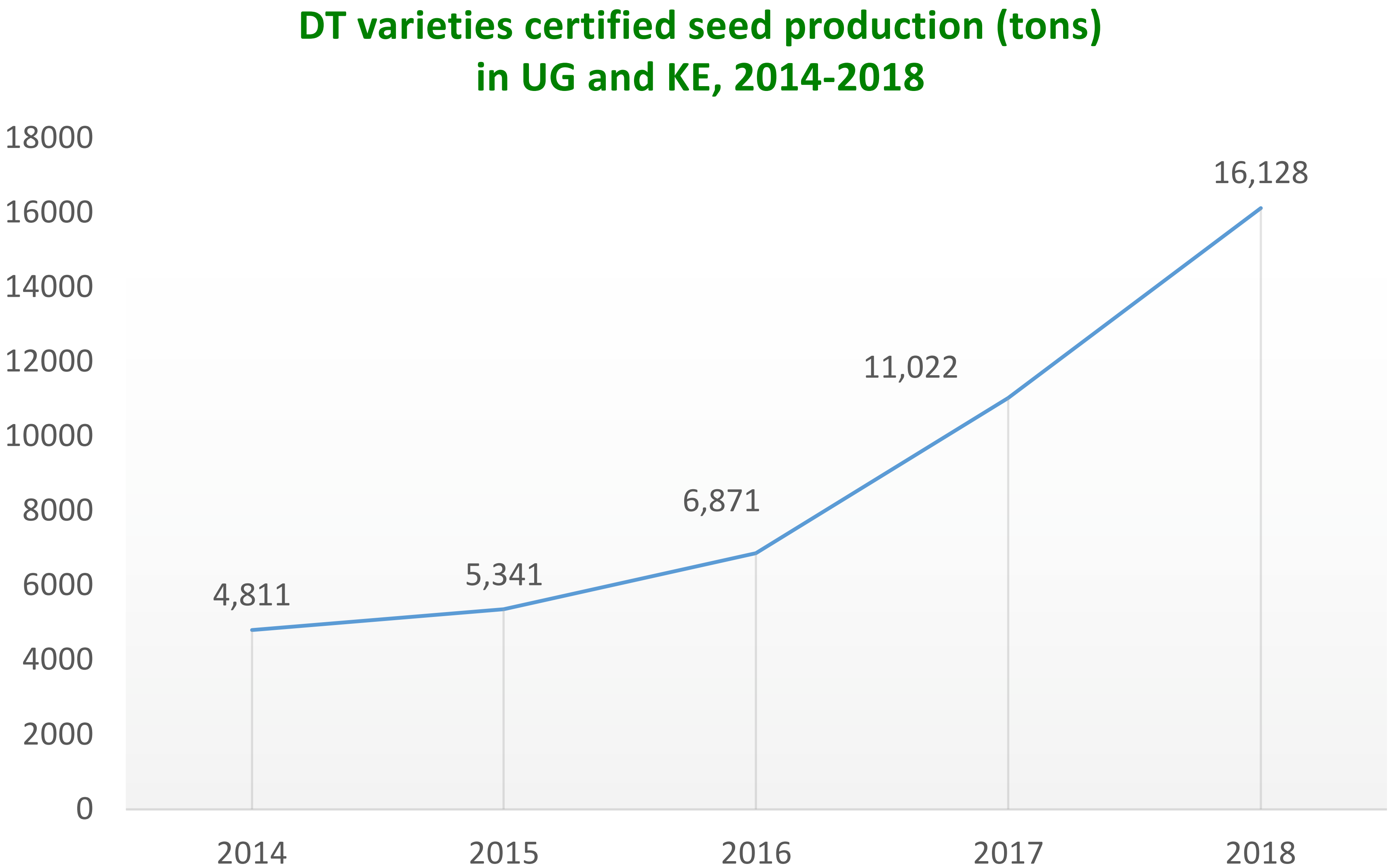
Are we achieving scale?



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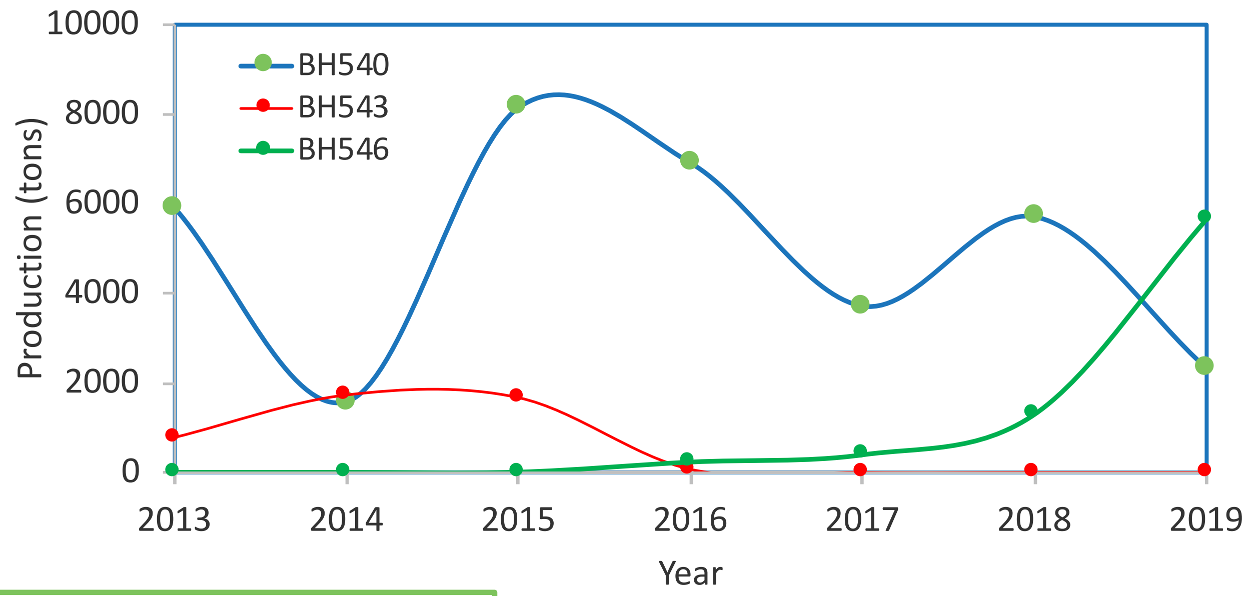
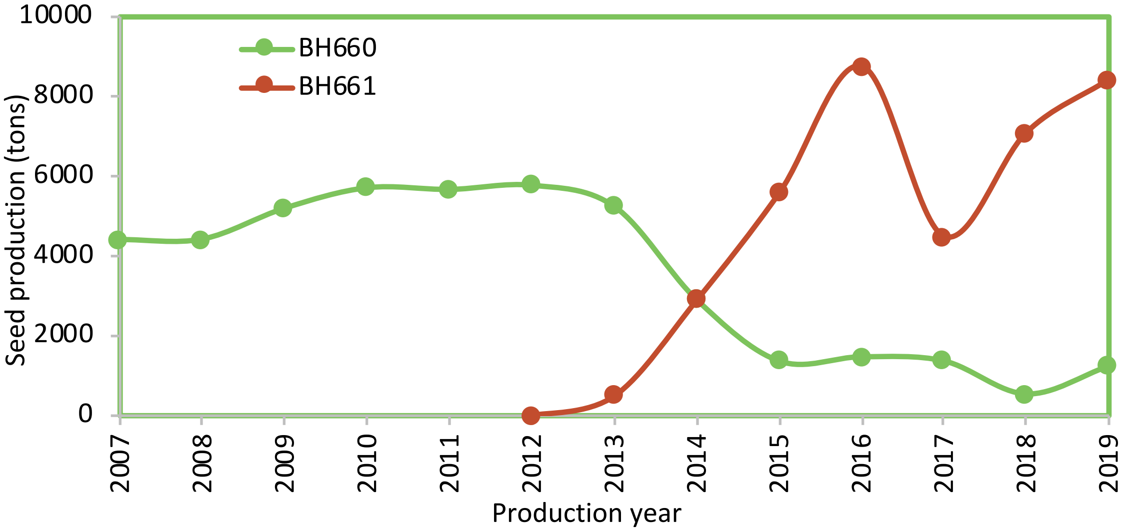
Variety Replacement in the Mid-/Upper-altitude, Ethiopia

BH546, medium maturity, 1000-1800 masl



BH661, late maturity, 1600-2200 masl



BH661, a DT maize hybrid, now occupies 17% of area under improved maize varieties in Ethiopia

Source: CIMMYT-Ethiopia

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DT Maize Adoption and Impacts in Africa (1/2)

Climate Change (2015) 133:283-299.

Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa

Monica Fisher[1] · Tsedeke Abate[2] · Rodney W. Lunduka[3] · Woinishet Asnake[4] · Yoseph Alemayehu[4] · Ruth B. Madulu[5]

Agriculture and Food Security (2017) 6:30.

RESEARCH Open Access

Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow?

Tsedeke Abate[1*], Monica Fisher[2,3], Tahirou Abdoulaye[4], Girma T. Kassie[5], Rodney Lunduka[6], Paswel Marenya[2] and Woinishet Asnake[2]

Food Security (2014) 6:217-230.

Evaluating the impact of improved maize varieties on food security in Rural Tanzania: Evidence from a continuous treatment approach

Menale Kassie · Moti Jaleta · Alessandra Mattei

International Food and Agribusiness Management Review 19A, 75-92

Targeting Drought-Tolerant Maize Varieties in Southern Africa: A Geospatial Crop Modeling Approach Using Big Data

Kindie Tesfaye[a], Kai Sonder[b], Jill Cairns[c], Cosmos Magorokosho[d], Amsal Tarekegn[e], Girma T. Kassie[f], Fite Getaneh[g], Tahirou Abdoulaye[h], Tsedeke Abate[i], and Olaf Erenstein[j]

Global Environmental Change 35 (2015) 82–92

The influence of gendered roles and responsibilities on the adoption of technologies that mitigate drought risk: The case of drought-tolerant maize seed in eastern Uganda

Monica Fisher[a,*], Edward R. Carr[b]

Climate and Development (2019) 11:35–46

Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe

Rodney Witman Lunduka, Kumbirai Ivyne Mateva, Cosmos Magorokosho & Pepukai Manjeru

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DT Maize Adoption and Impacts in Africa (2/2)

Land Use Policy 88 (2019) 104091

Impacts of drought-tolerant maize varieties on productivity, risk, and resource use: Evidence from Uganda

Franklin Simtowe[a,*], Emily Amondo[b], Paswel Marenya[a], Dil Rahut[c], Kai Sonder[c], Olaf Erenstein[c]

IJCCSM 11, 570-591

Productivity and production risk effects of adopting drought-tolerant maize varieties in Zambia

E Amondo, F Simtowe, D Rahut, O Erenstein

Agricultural and Food Economics (2019) 7:15

Heterogeneous seed access and information exposure: implications for the adoption of drought-tolerant maize varieties in Uganda

F Simtowe, P Marenya, E Amondo, M Worku, D Rahut, O Erenstein

Food Sec. (2015) 7:1225–1238

Subsidies promote use of drought tolerant maize varieties despite variable yield performance under smallholder environments in Malawi

Stein T. Holden[1] · Monica Fisher[2]

World Development Vol. 94, pp. 465–477, 2017

Modeling Preference and Willingness to Pay for Drought Tolerance (DT) in Maize in Rural Zimbabwe

GIRMA T. KASSIE[a], AWUDU ABDULAI[b], WILLIAM H. GREENE[c], BEKELE SHIFERAW[d], TSEDEKE ABATE[e], AMSAL TAREKEGNE[f] and CHLOE SUTCLIFFE[g,*]

Journal of Agricultural Economics, Vol. 70, No. 1, 2019, 198–214

Adoption of Drought Tolerant Maize Varieties under Rainfall Stress in Malawi

Samson P. Katengeza, Stein T. Holden and Rodney W. Lunduka[1]

Journal of Environmental Management 203 (2017) 106–113

Measuring the impacts of adaptation strategies to drought stress: The case of drought tolerant maize varieties

Tesfamicheal Wossen [a,*], Tahirou Abdoulaye [b], Arega Alene [c], Shiferaw Feleke [d], Abebe Menkir [b], Victor Manyong [d]

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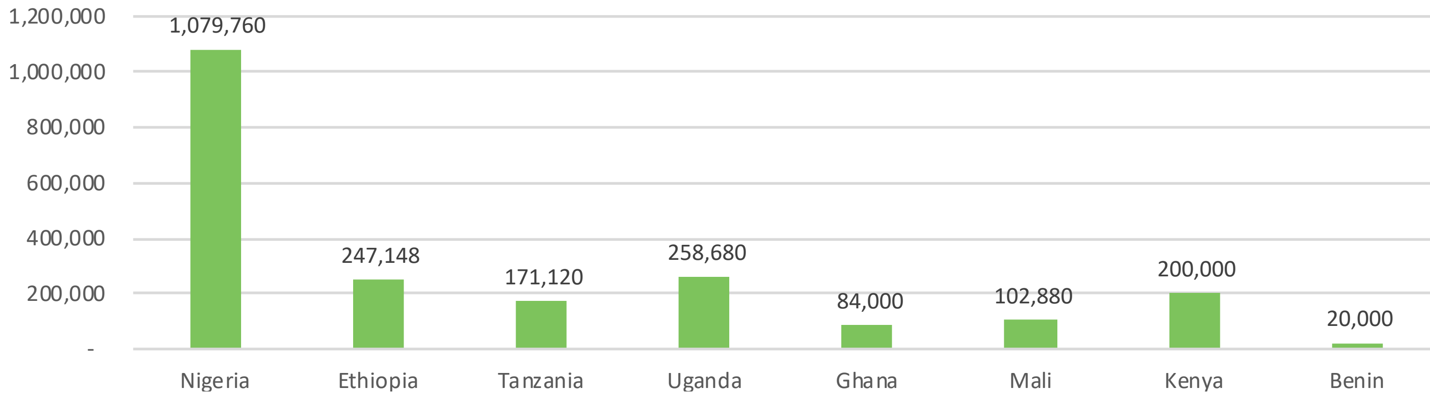
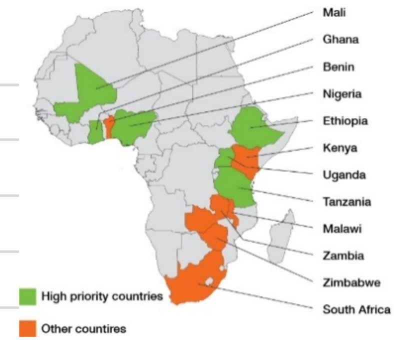
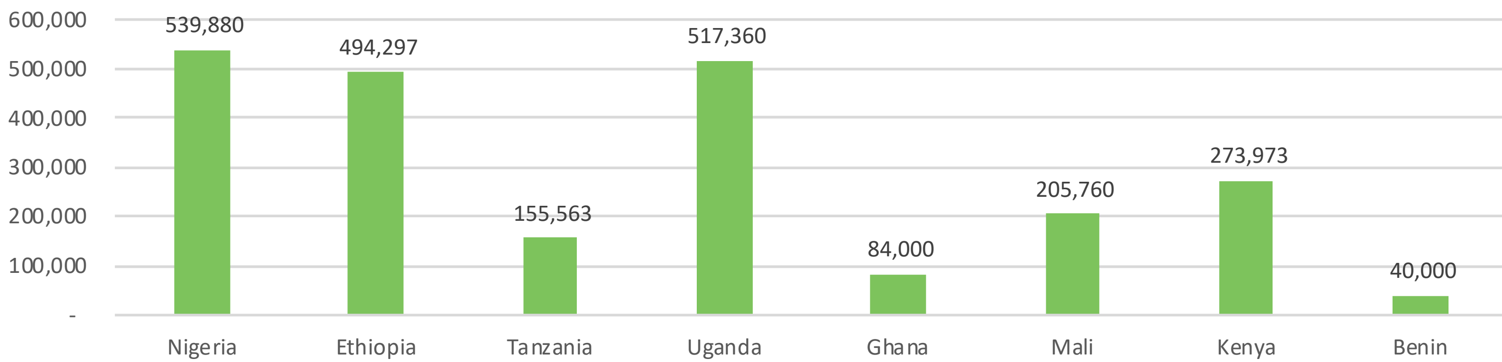
Estimated stress tolerant maize area and households-2018

Area planted with stress tolerant varieties, 2018





Farmers planting ST varieties, 2018



Compiled by Franklin Simtowe and team
STMA: Stress tolerant maize for Africa-2018

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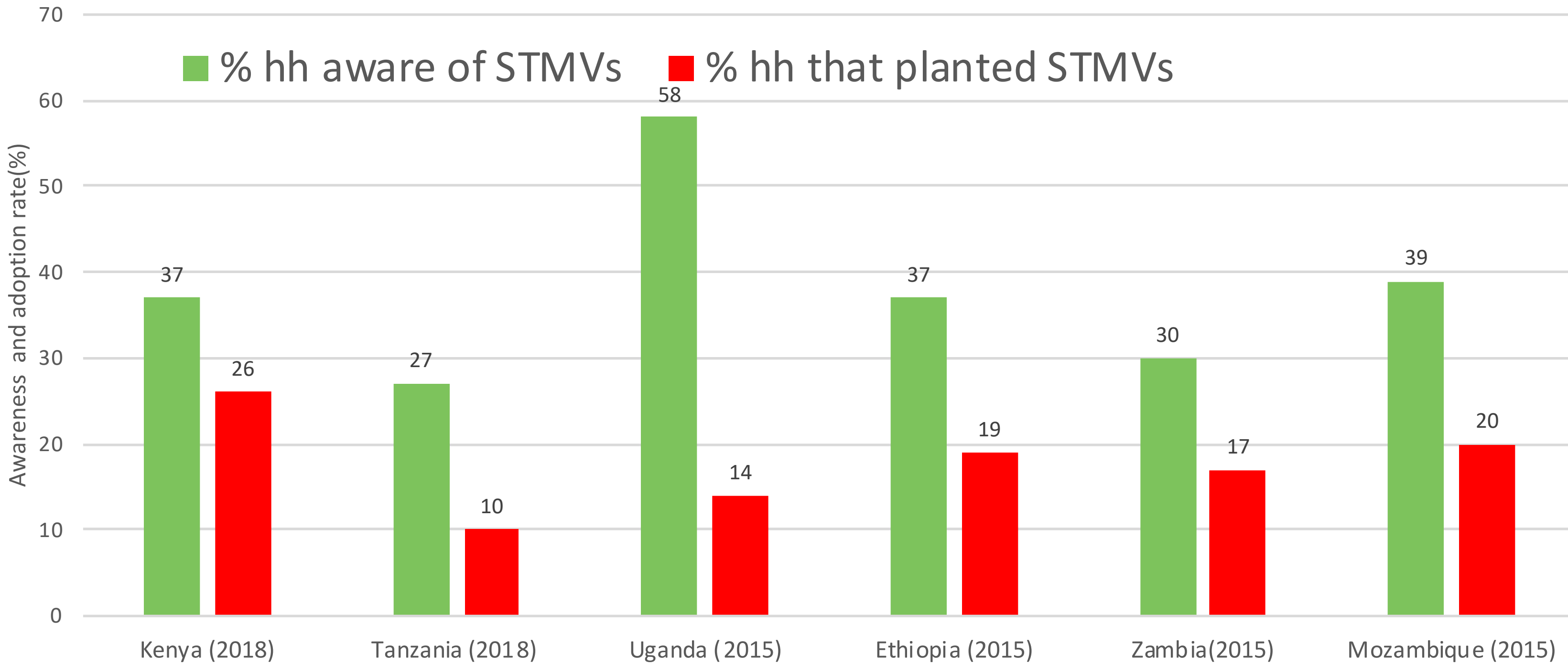
% households aware of STMVs and adoption rates based on hh surveys



-Reasons for Non-adoption are many: Knowledge, seed availability, price of seed, farmer preferences…

- These have policy and technical implications

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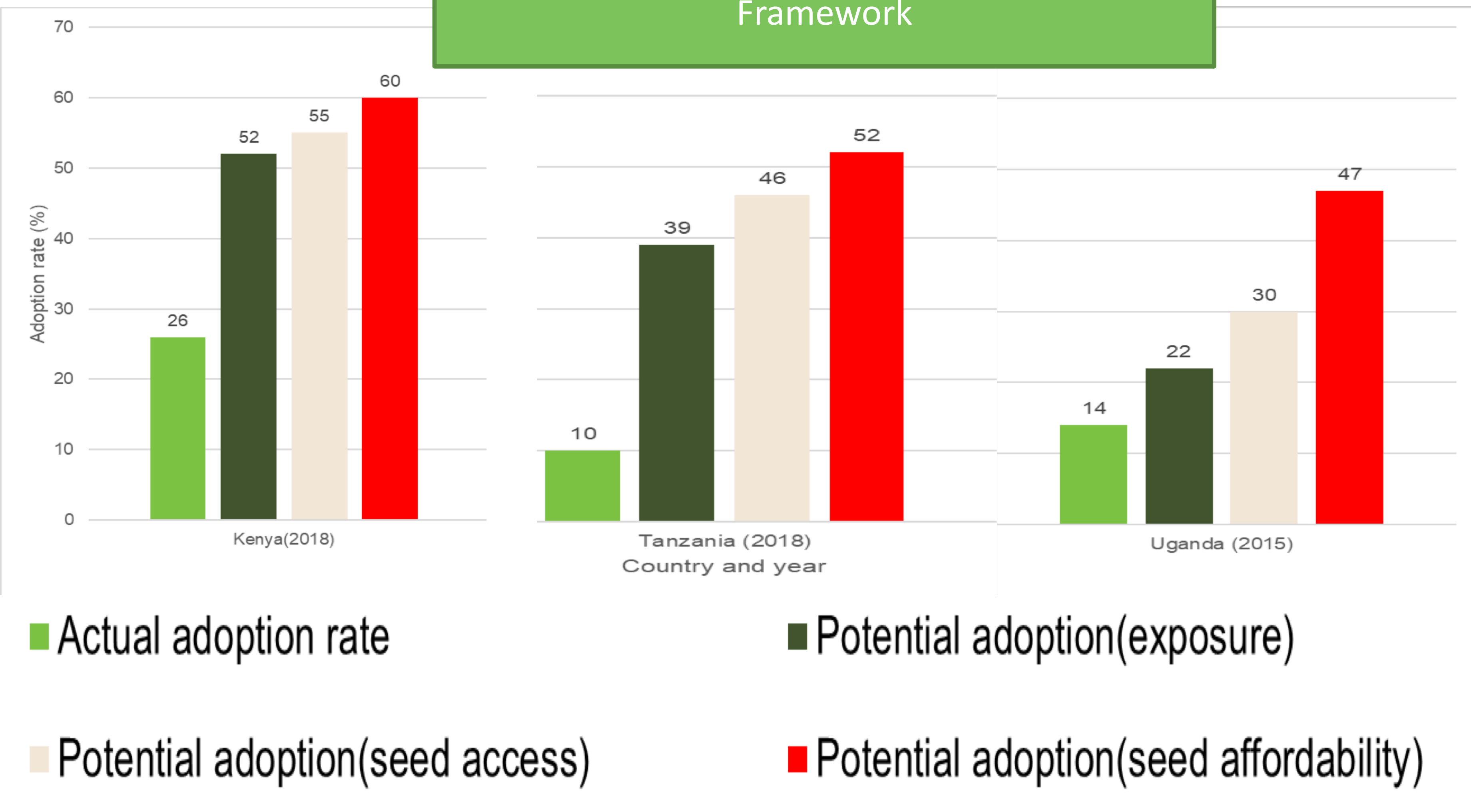
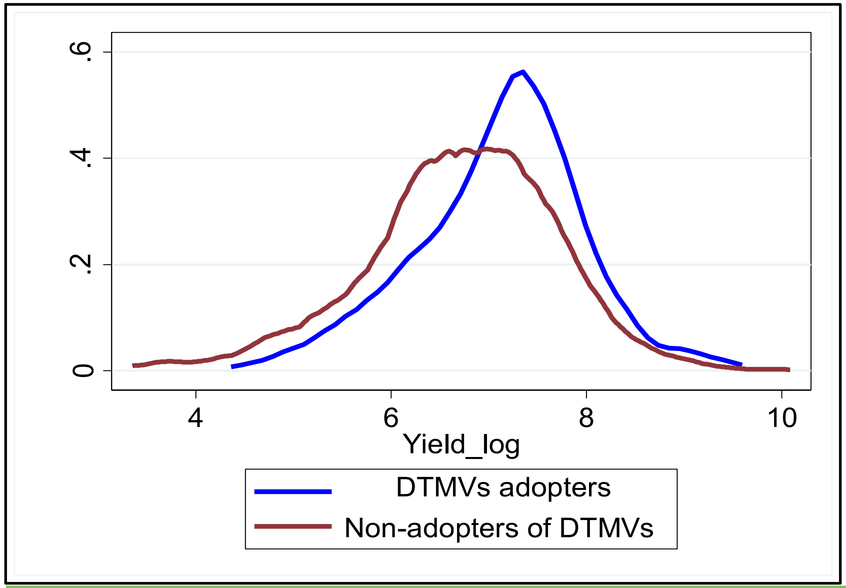
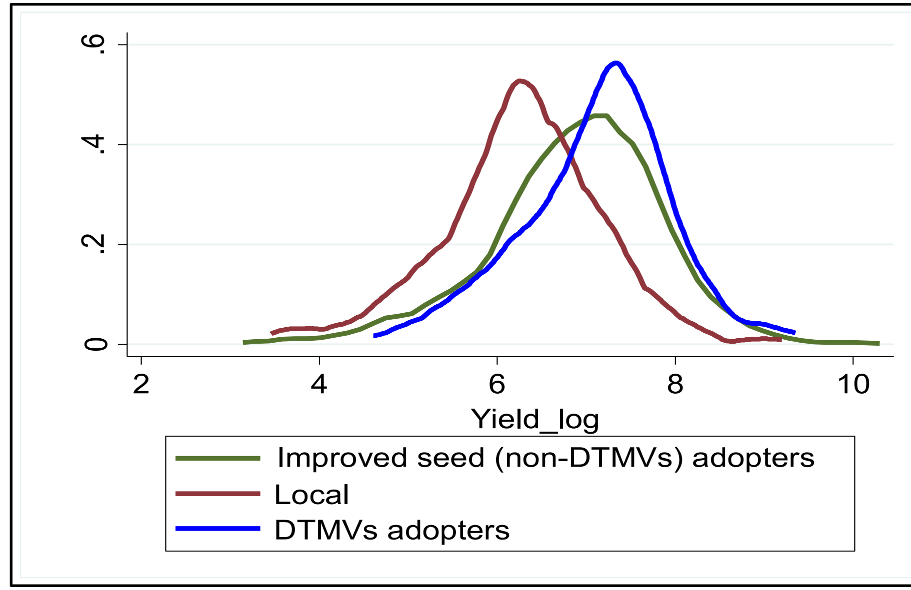
Potential adoption rates if farmers have information, seed and price is affordable

Based on the Average Treatment Effects Framework



The Impact of STM on yield in Zambia

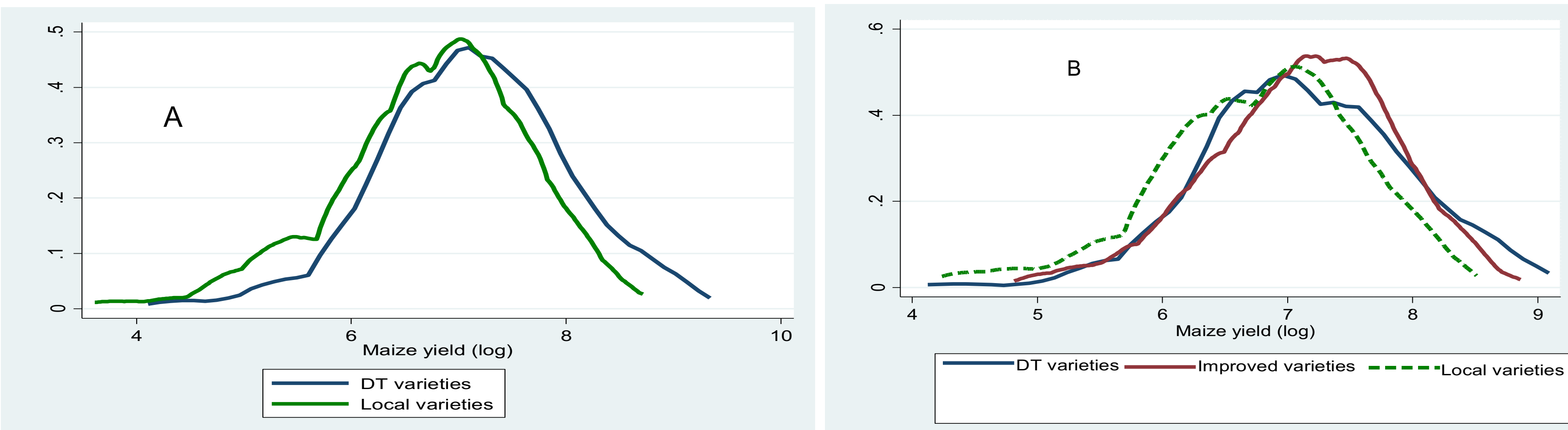




Outcome variables	Household type and treatment effect	Decision stage		Effect on adoption	Change (%)
		To Adopt	Not to adopt		
Average maize yield (log)	DTMVs Adopters (ATT)	7.10	6.17	0.93***	15
Average maize Variance (log)	ATT	12.80	20.75	-7.95***	-38
Average yield skewness (log)	ATT	14.69	10.84	3.85***	35.5

Amondo et al, 2019

The impact of STM on yield in Uganda



Outcome variables					
		Adopters	Non-adopters	Effect on adoption	Change%
Average maize yield	(ATT)	7.18	6.22	0.96***	16
Average skewness	Adopters (ATT)	14.71	11.3	3.41***	30

Simtowe et al, 2019 (LUP)

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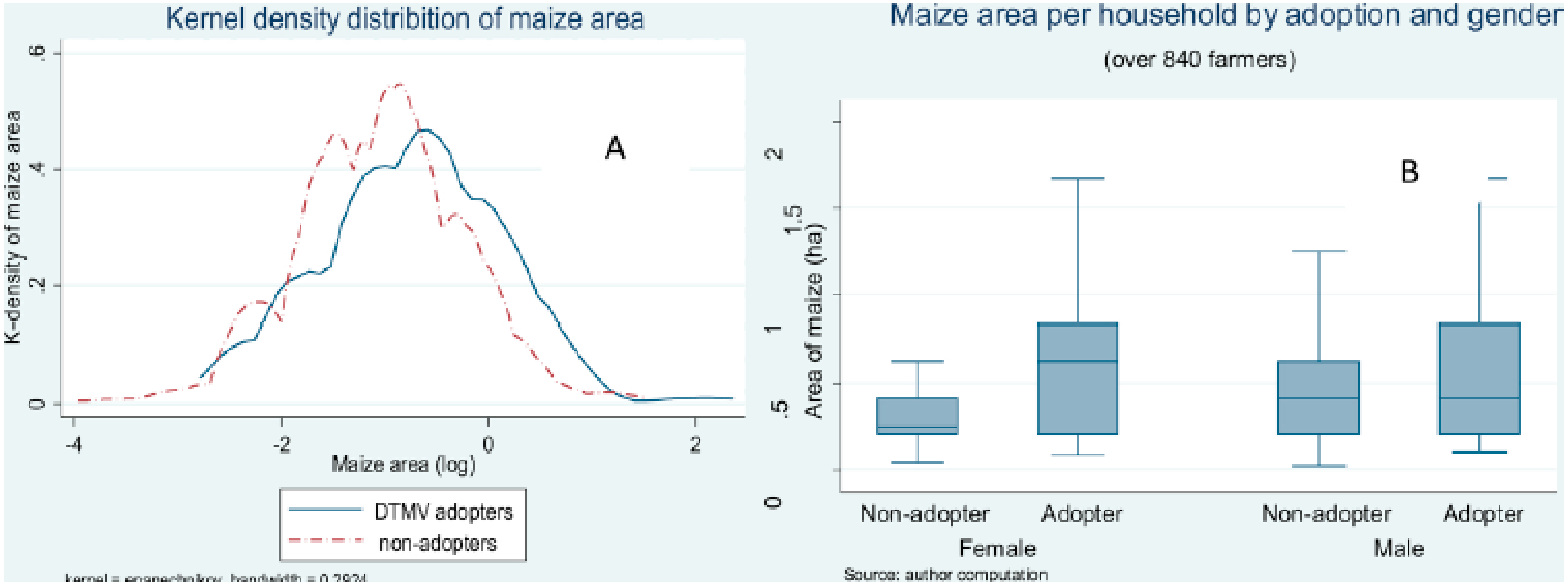
The Impact of STMV Maize area in Uganda



Kennel density distribution and the area of maize among adopters and non-adopters

- ST adoption increases investment on the extensive and intensive margin
- Female farmers particularly, tend to increase maize land when they grow STM
- They also tend to hire more labor (intensive margin)

Simtowe et al, 2019 (LUP)

Summing up

- Supply & demand for DT maize increasing
- Drought tolerance vs drought resistance
  - Timing & intensity
- Bundling diverse traits
  - Stress tolerance - beyond drought
  - Selected for good performance under both good and stressed conditions
- DT maize +ve impacts on farmer yields
  - levels & distribution

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Thanks!

- **MAIZE Partners** in Africa, Asia and LatAm for their tremendous support
- **Funding agencies,** especially Bill & Melinda Gates Foundation, USAID, DFID, Syngenta Foundation for Sustainable Agriculture, and MAIZE CRP.
- **CIMMYT colleagues** for their commitment to the mission