

The Promise of Drought Tolerant Seed Technologies

B.M. Prasanna, Franklin Simtowe & Olaf Erenstein
International Maize and Wheat Improvement Center
(CIMMYT)

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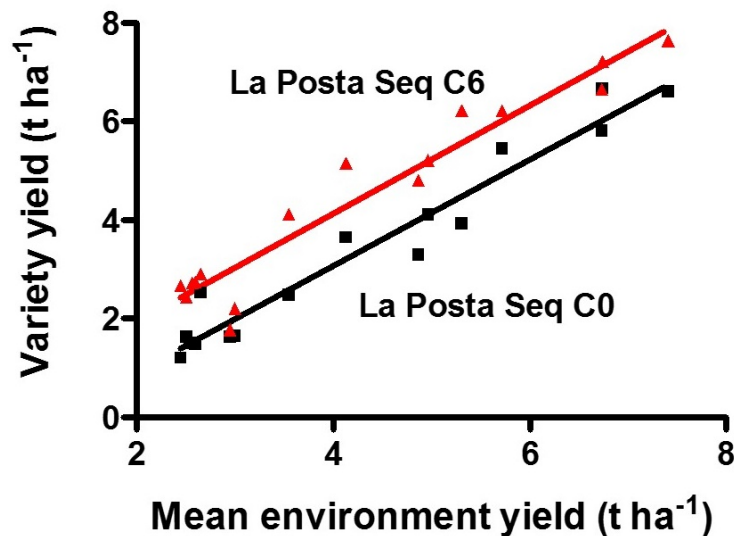
Drought Tolerant Maize-Index Insurance Pilot Project
Meeting, Washington DC



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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.

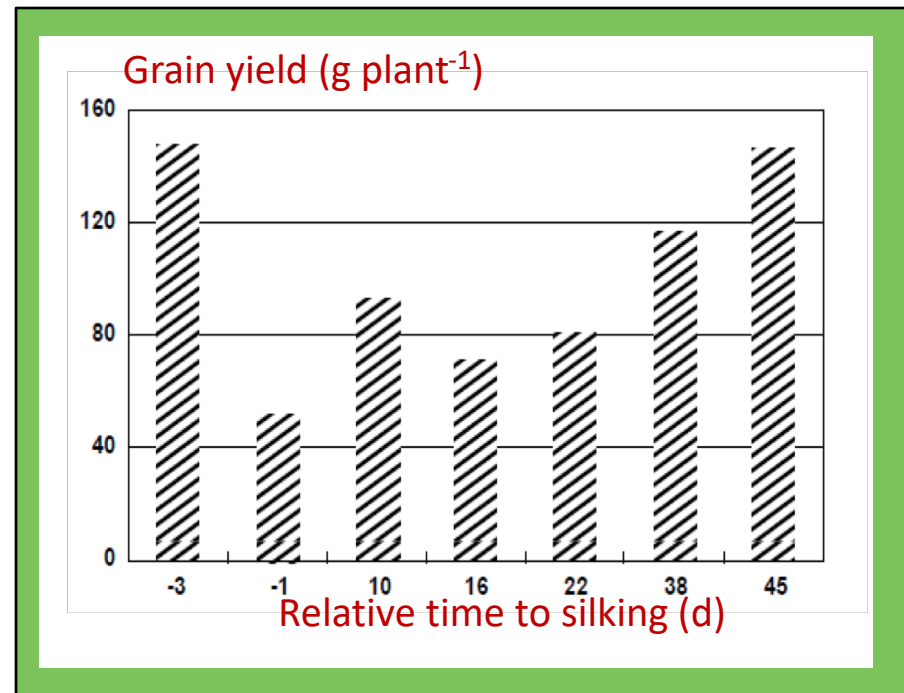
Breeding for drought tolerance at CIMMYT is nearly four decades old...

- Well-constituted pools and populations (e.g., La Posta Secuia, 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)



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



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.

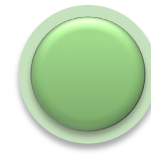
Pillars to increase phenotyping accuracy and efficiency



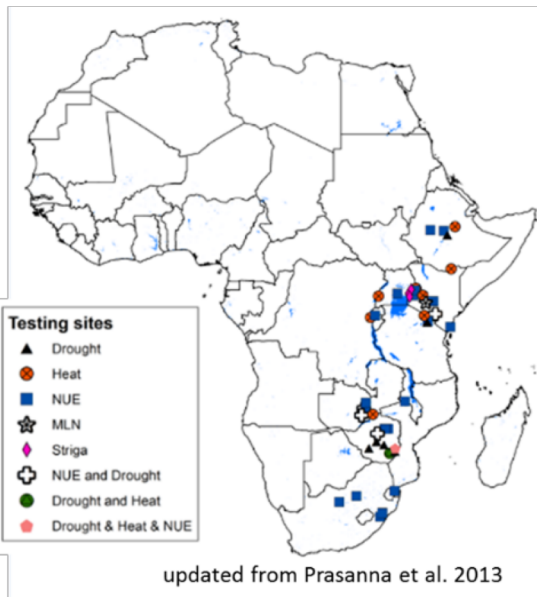
Network



Protocols



Data collection methods



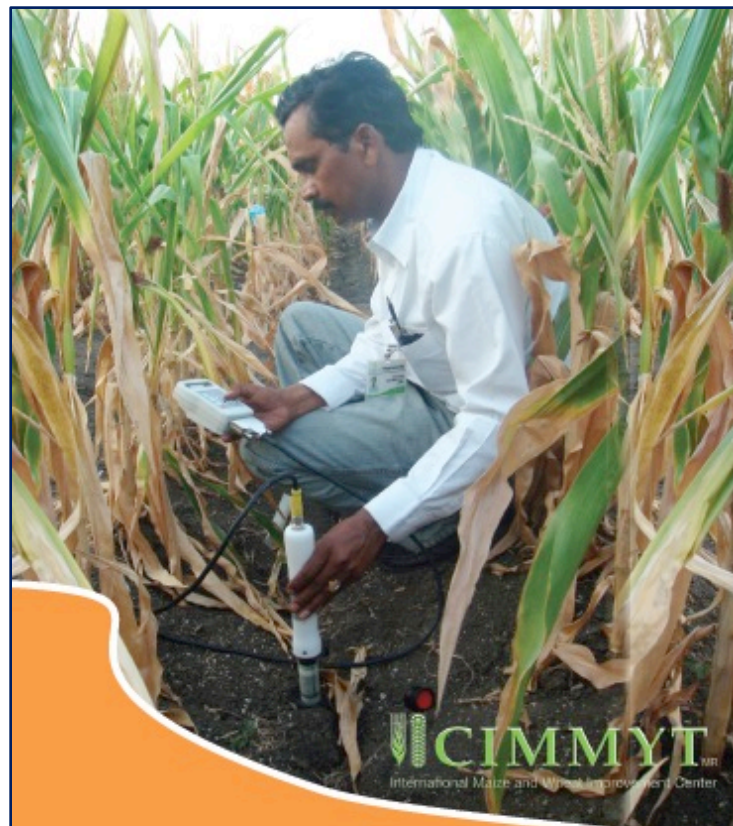
Harmonized Phenotyping Protocols



PHENOTYPING FOR ABIOTIC
STRESS TOLERANCE IN MAIZE:

DROUGHT STRESS

M. Zaman-Allah, P.H. Zaidi, S. Trachsel,
J.E. Cairns, M.T. Vinayan and K. Seetharam



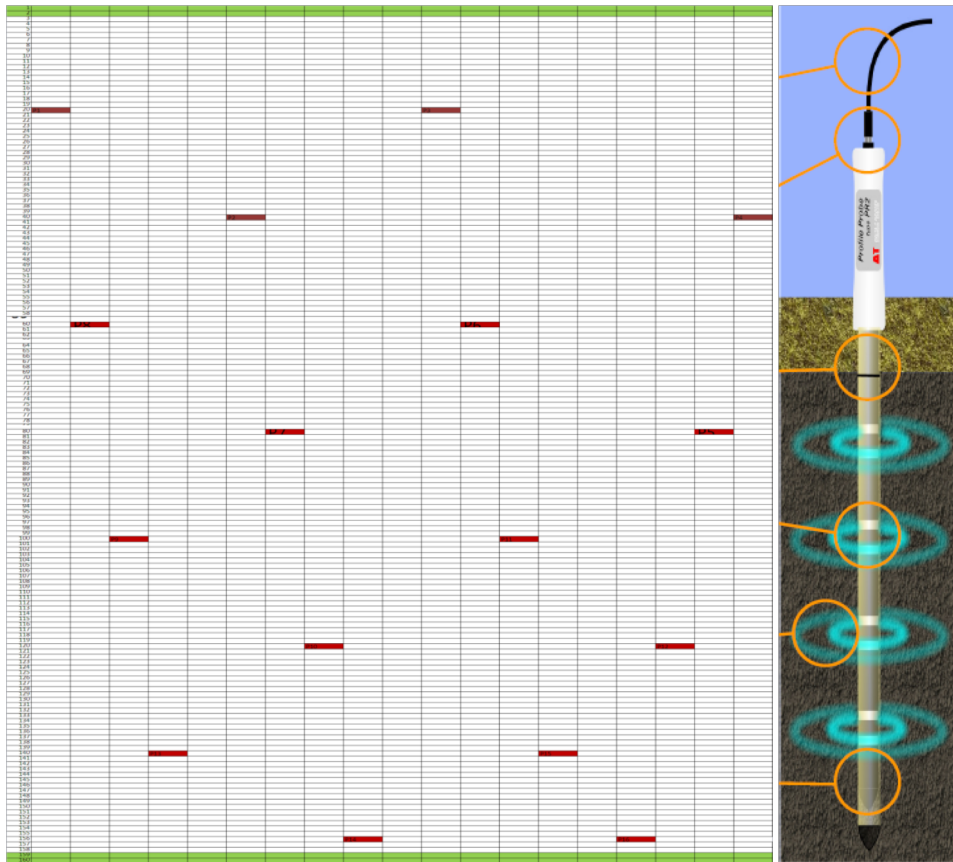
Management of **drought stress** in field phenotyping

Pervez H. Zaidi
CIMMYT-Asia Maize Program
ICRISAT Campus, Hyderabad, India



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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-Jan	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

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

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



Commercial check

Released hybrid



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



CKDHL0323

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



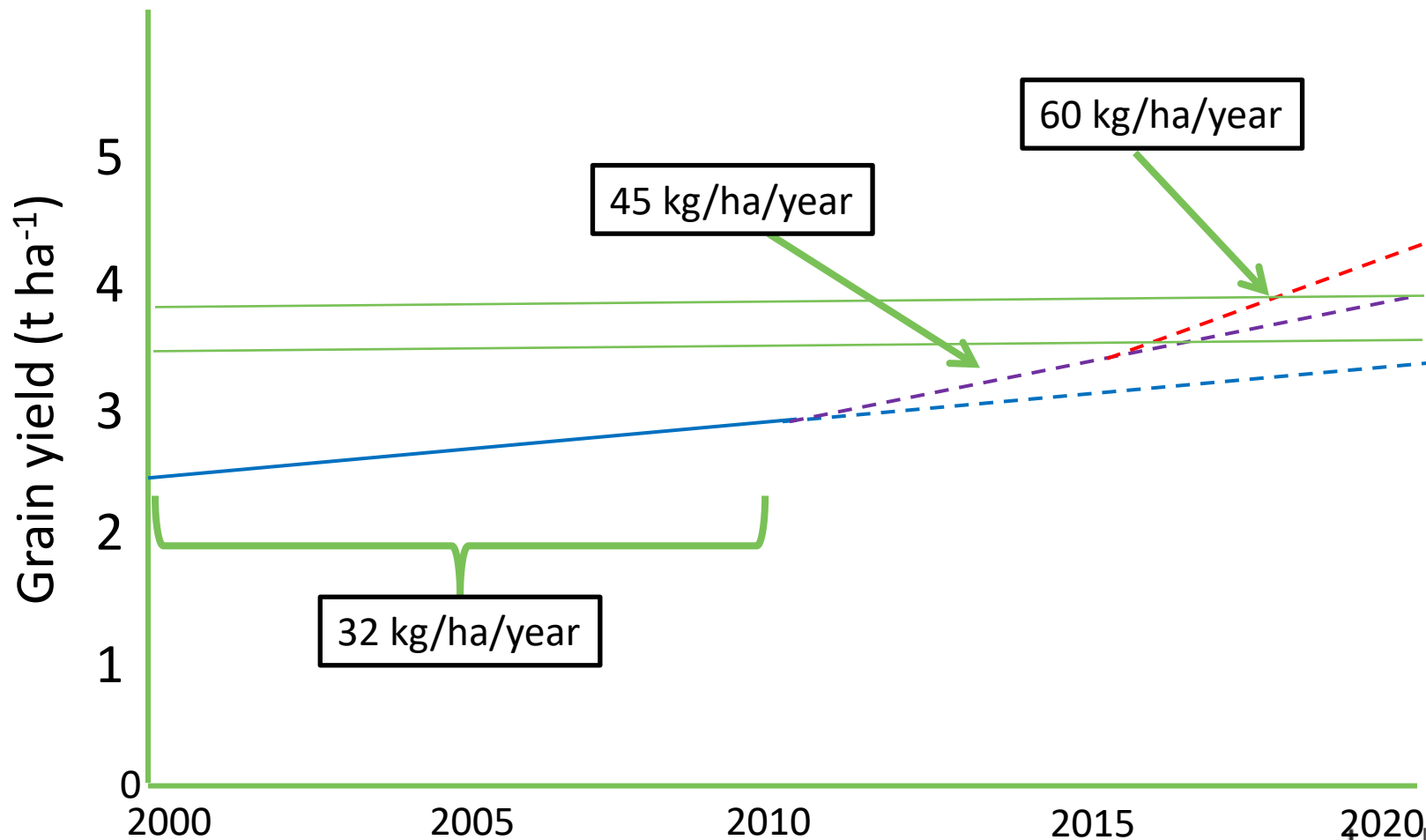
MH28, a DT hybrid



Commercial drought-susceptible hybrids



Driving Genetic Gain under Drought-prone Environments



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.



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

DT Maize Adoption and Impacts in Africa

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 Fisher¹ · Tsedeke Abate² ·
Rodney W. Lunduka³ · Woinishet Asnake⁴ ·
Yoseph Alemayehu⁴ · Ruth B. Madulu⁵

Agriculture and Food Security (2017) 6:30.

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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 Abdoulaye⁴, Girma T. Kassie⁵, Rodney Lunduka⁶, Paswel Marenya⁷ and Woinishet Asnake²

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

Agricultural Economics (2015) 46:1-12.

Ex post impacts of improved maize varieties on poverty in rural Ethiopia

Di Zeng^{a,*}, Jeffrey Alwang^a, George W. Norton^a, Bekele Shiferaw^b, Moti Jaleta^c, Chilot Yirga^d

^aDepartment of Agricultural and Applied Economics, Virginia Tech, Blacksburg, VA 24061, USA

^bPartnership for Economic Policy, P.O. Box 30772-00100, Nairobi 00621, Kenya

^cInternational Maize and Wheat Improvement Center, P.O. Box 5689, Addis Ababa, Ethiopia

^dEthiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia

Climate and Development (2017) <https://doi.org/10.1080/17565529.2017.1372269>.

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

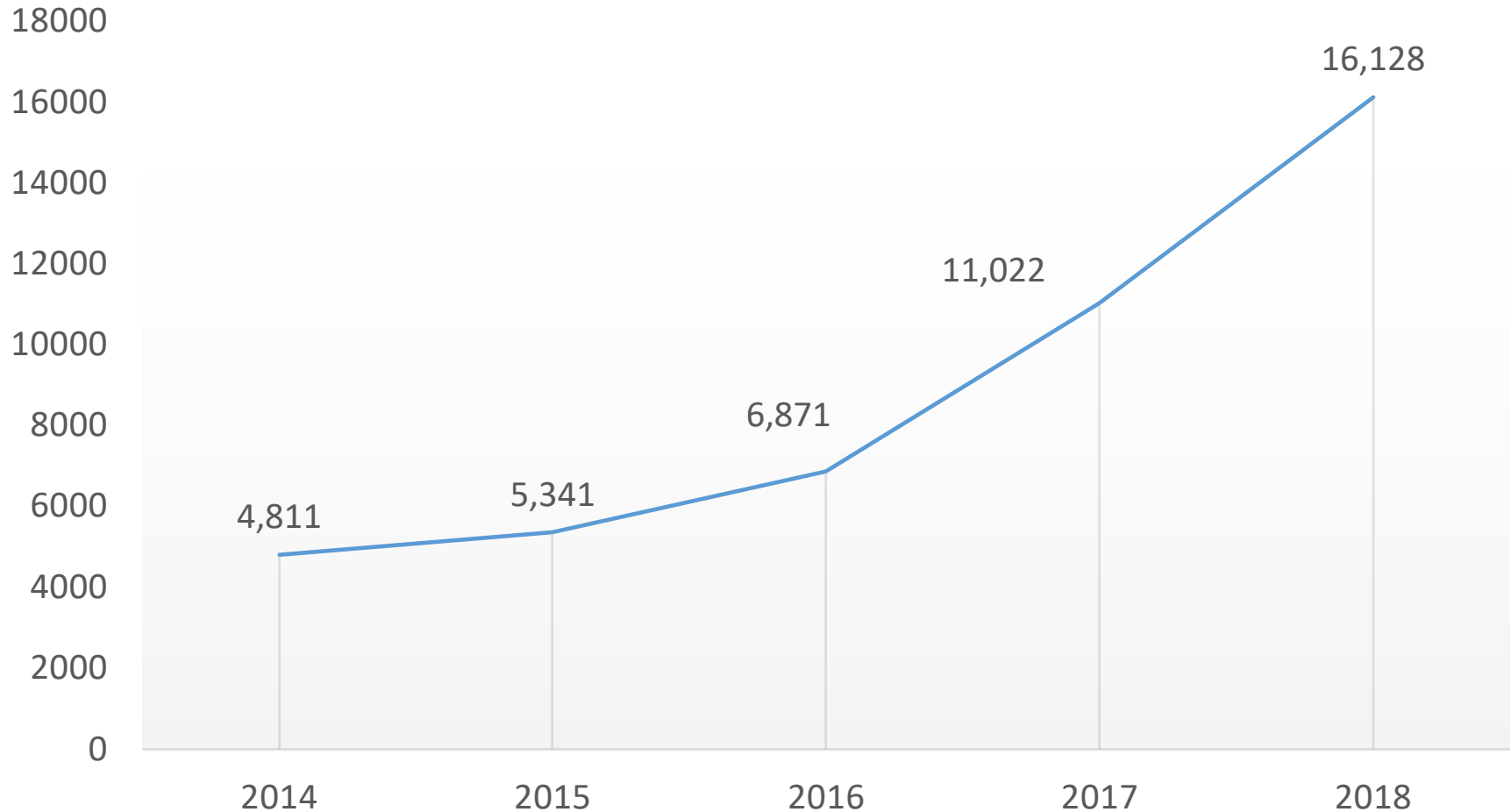
Rodney Witman Lunduka, Kumbirai Ivyne Mateva, Cosmos Magorokosho & Pepukai Manjeru



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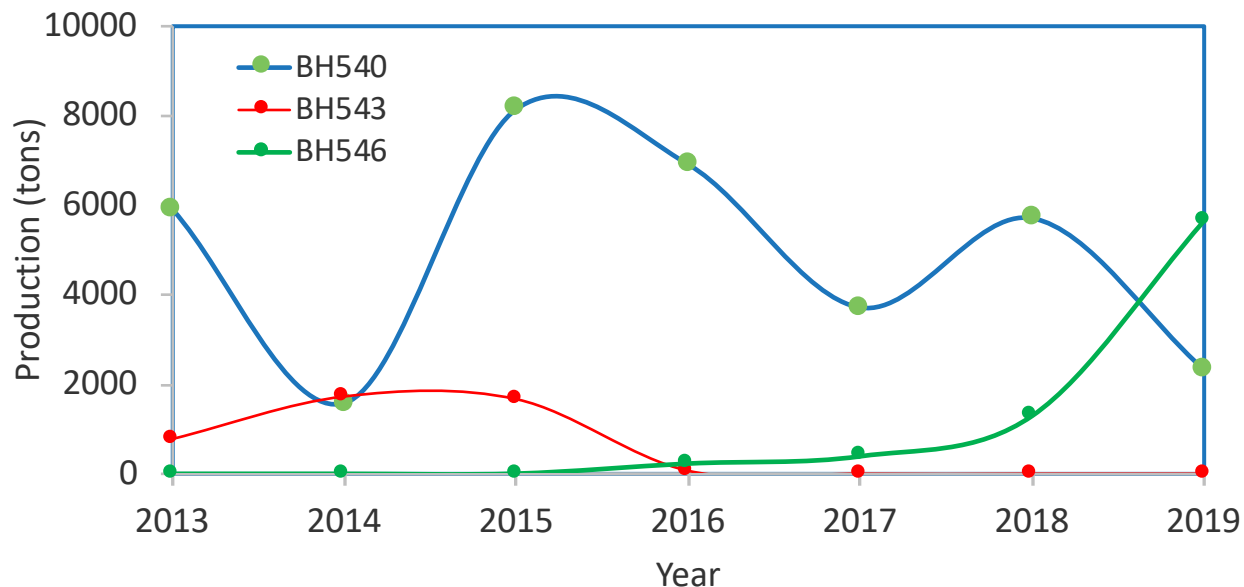
Are we achieving scale?

**DT varieties certified seed production (tons)
in UG and KE, 2014-2018**

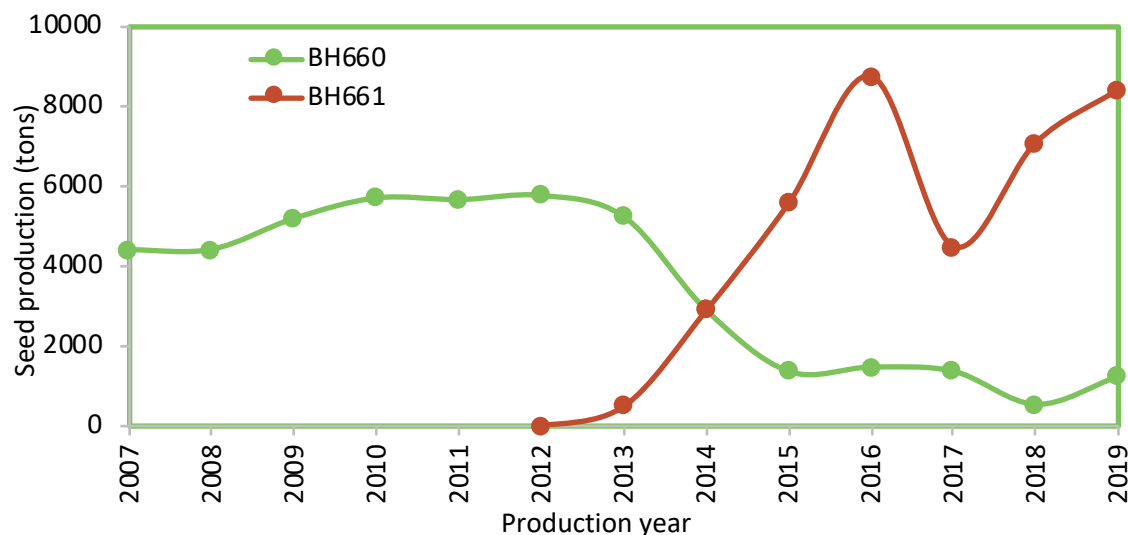


Variety Replacement in the Mid-/Upper-altitude, Ethiopia

BH546, medium maturity, 1000-1800 masl



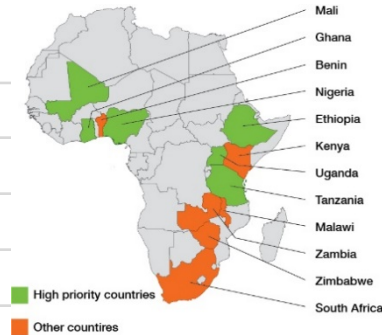
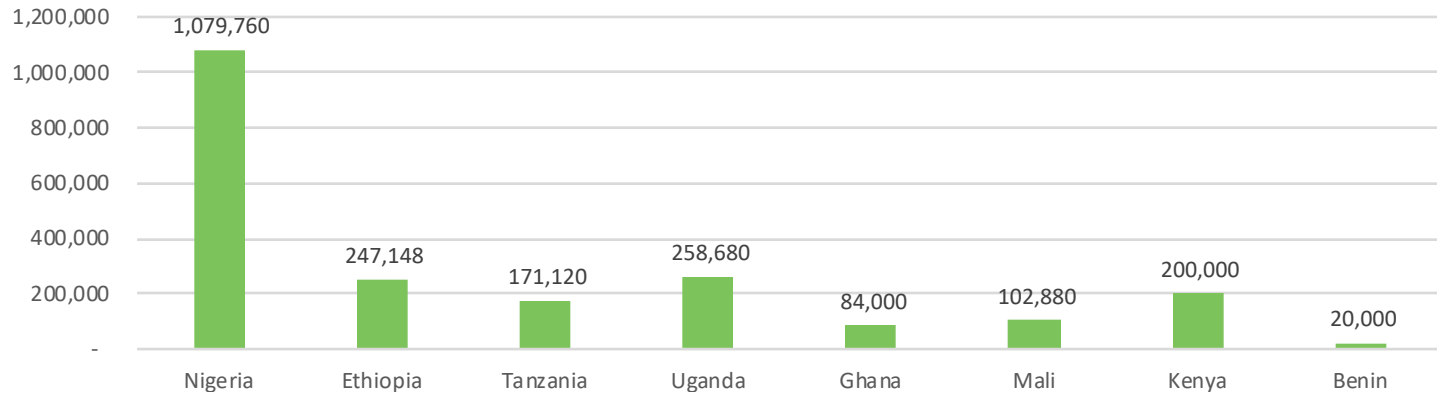
BH661, late maturity, 1600-2200 masl



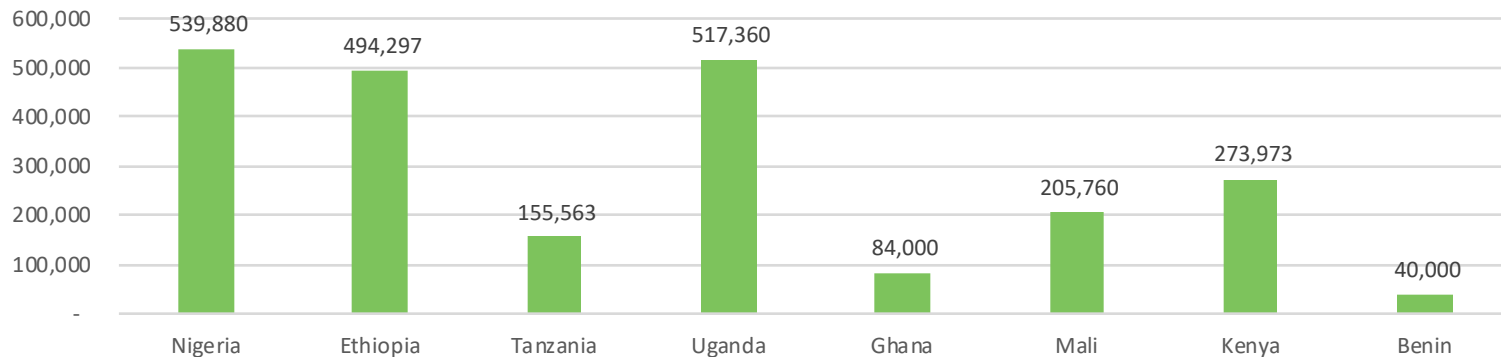
BH661, a DT maize hybrid, now occupies 17% of area under improved maize varieties in Ethiopia

Estimated stress tolerant maize area and households-2018

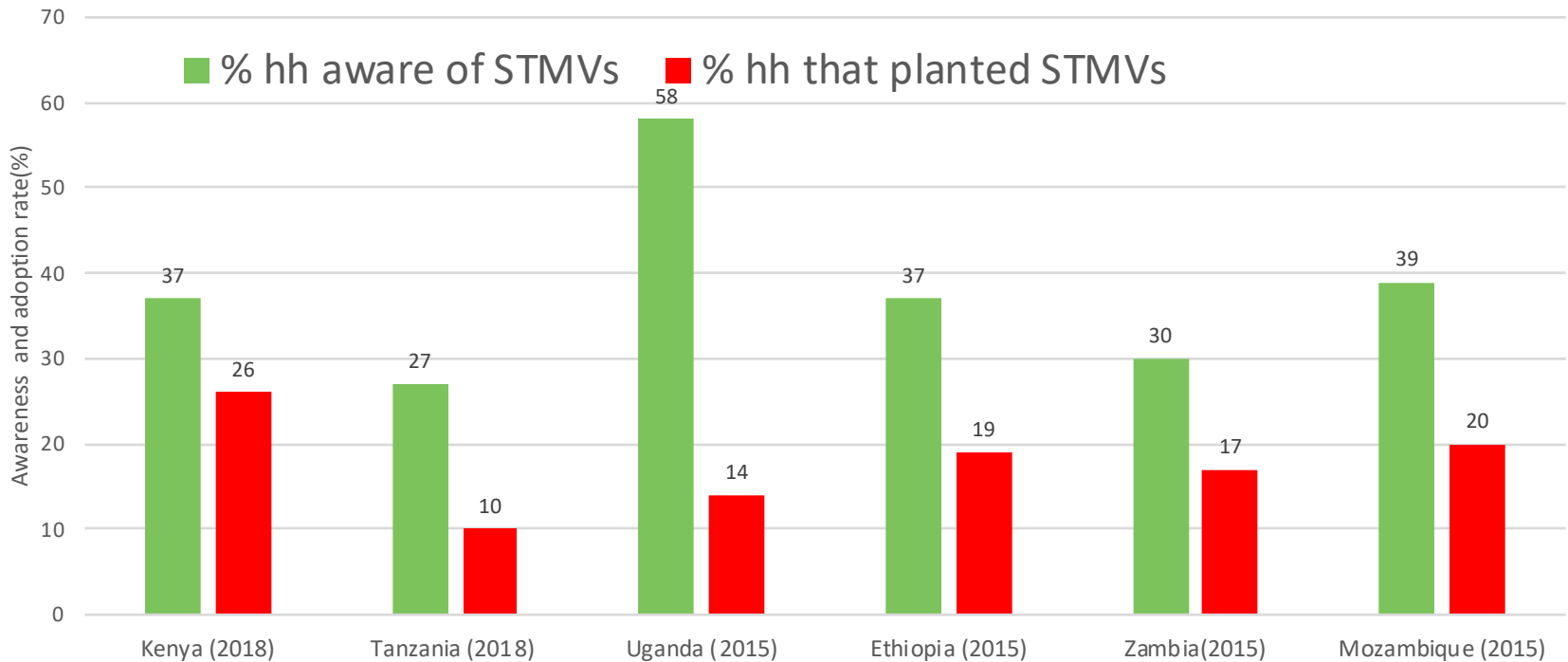
Area planted with stress tolerant varieties, 2018



Farmers planting ST varieties, 2018



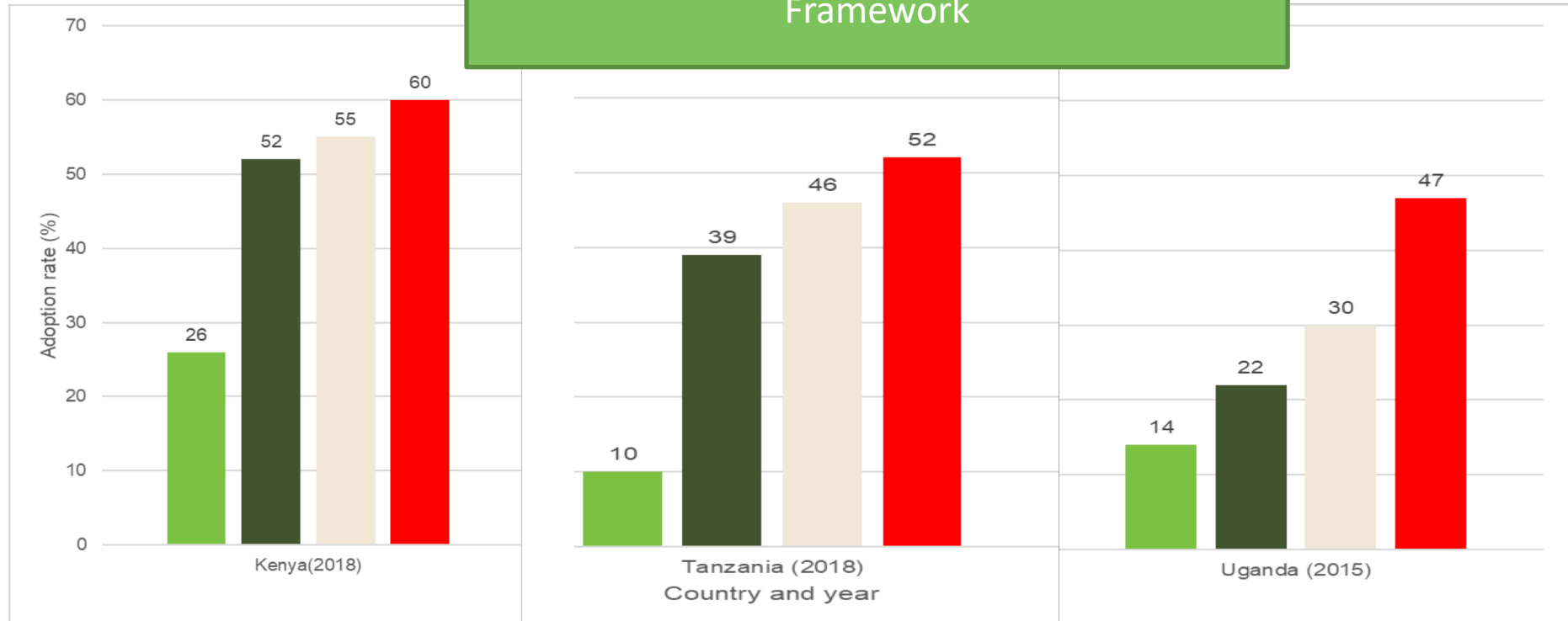
% households aware of STMVs and adoption rates based on hh surveys



- Reasons for Non-adoption are many: Knowledge, seed availability, price of seed, farmer preferences...
- These have policy and technical implications

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

Based on the Average Treatment Effects Framework



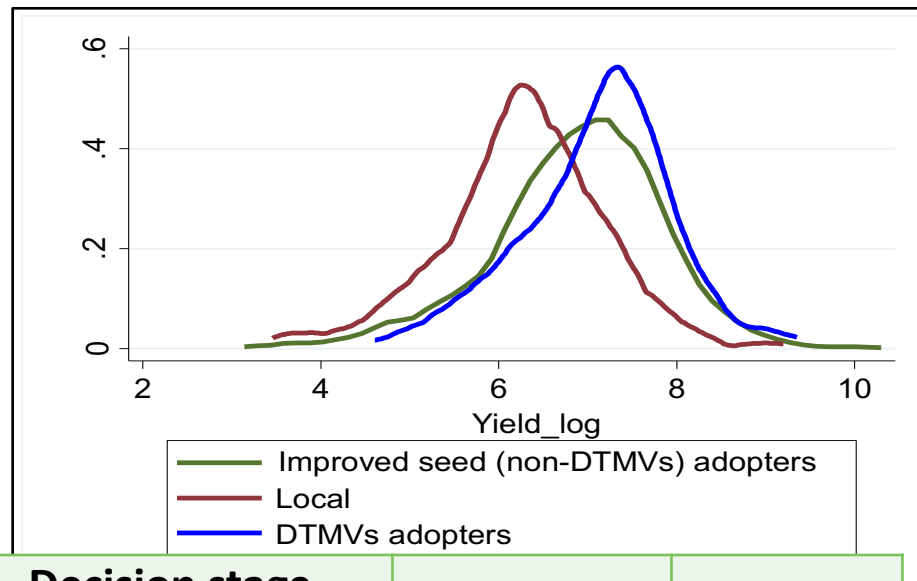
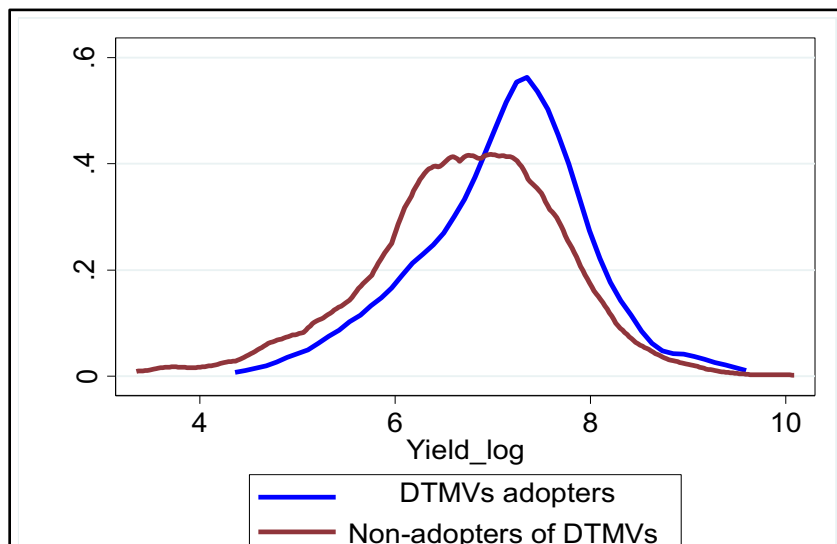
■ Actual adoption rate

■ Potential adoption(exposure)

■ Potential adoption(seed access)

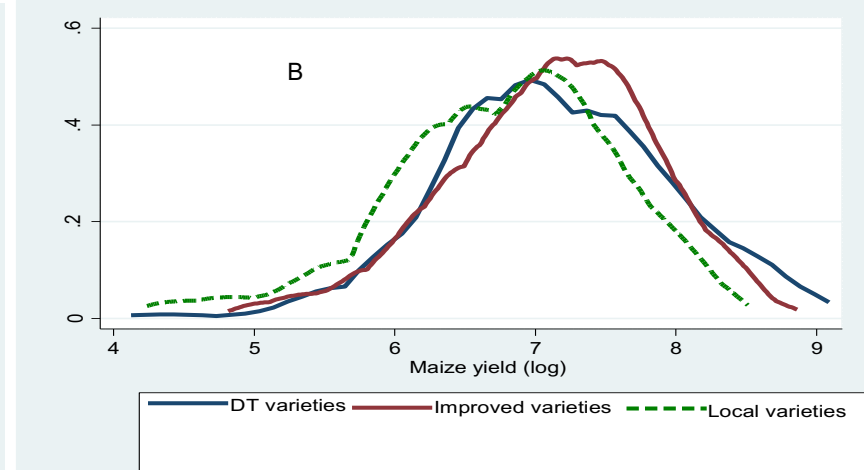
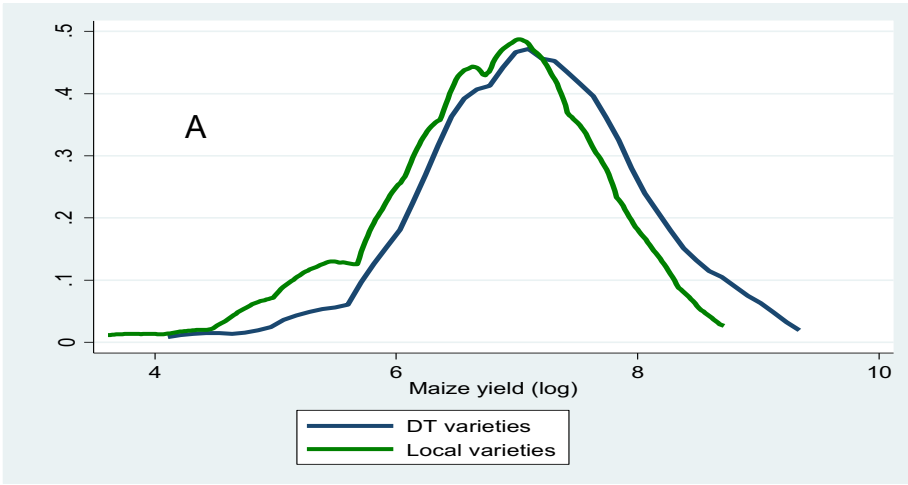
■ Potential adoption(seed affordability)

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
	Non-adopters (ATU)	6.64	6.75	-0.11***	-1.6
	Heterogeneity effect	0.46	-0.58	1.03	
Average maize Variance (log)	ATT	12.80	20.75	-7.95***	-38
	ATU	12.77	13.01	-0.24***	-1.8
	Heterogeneity effect	0.03	7.74	-7.71	
Average yield skewness (log)	ATT	14.69	10.84	3.85***	35.5
	ATU	13.15	14.32	-1.16***	-8.1

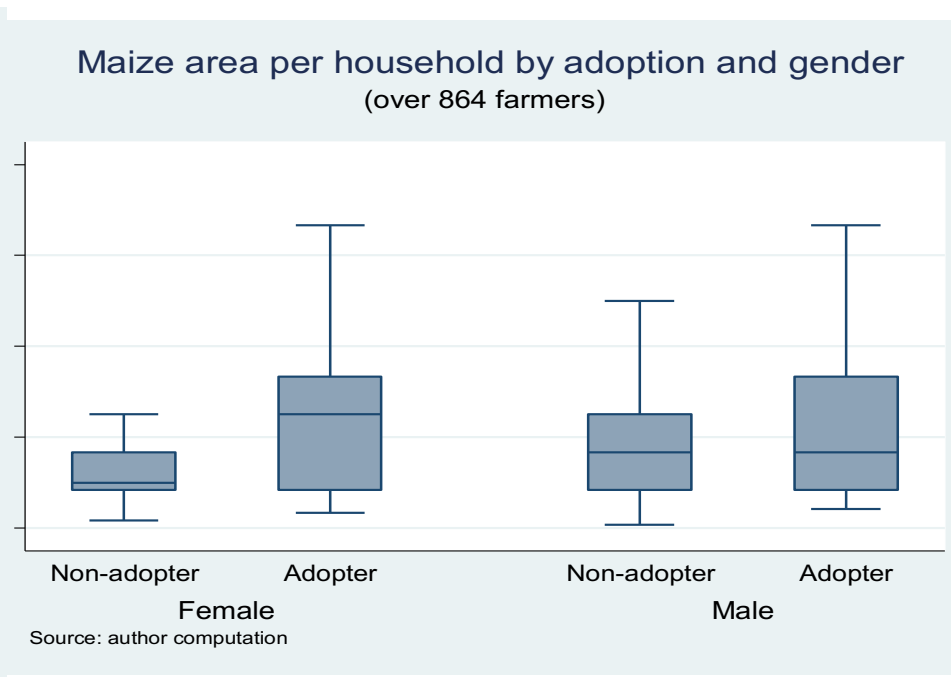
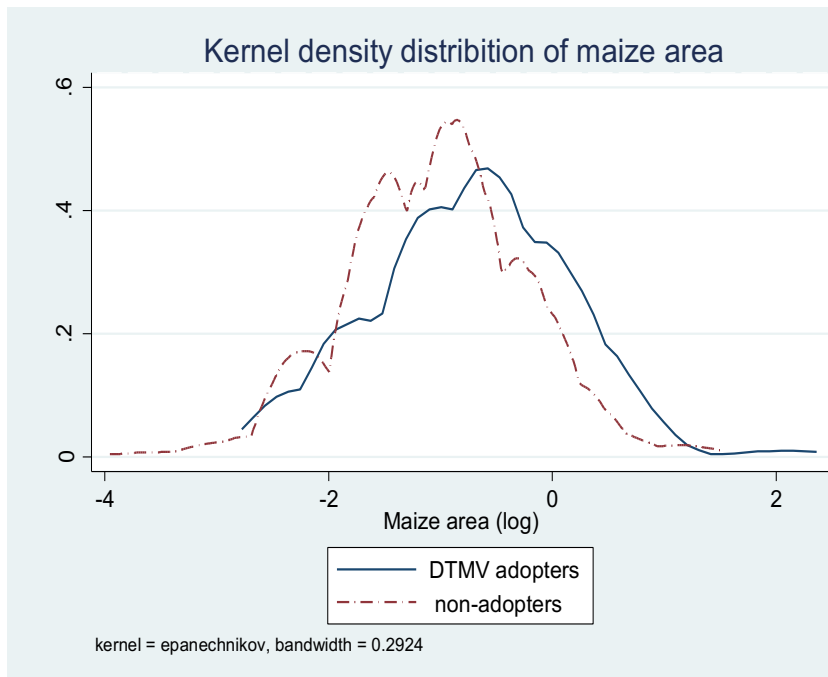
The impact of STM on yield in Uganda



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

The Impact of STMV Maize area in Uganda



Kernel 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)

Summing up

- Supply & demand for DT 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

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