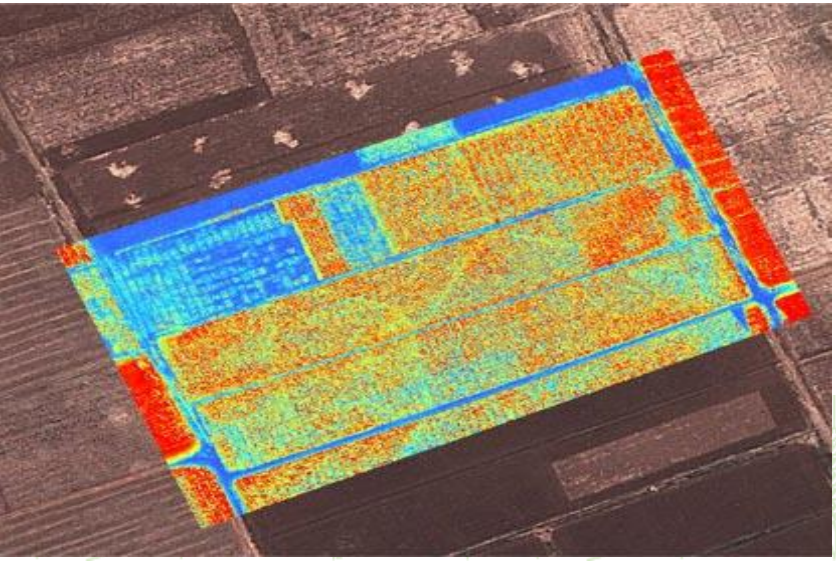
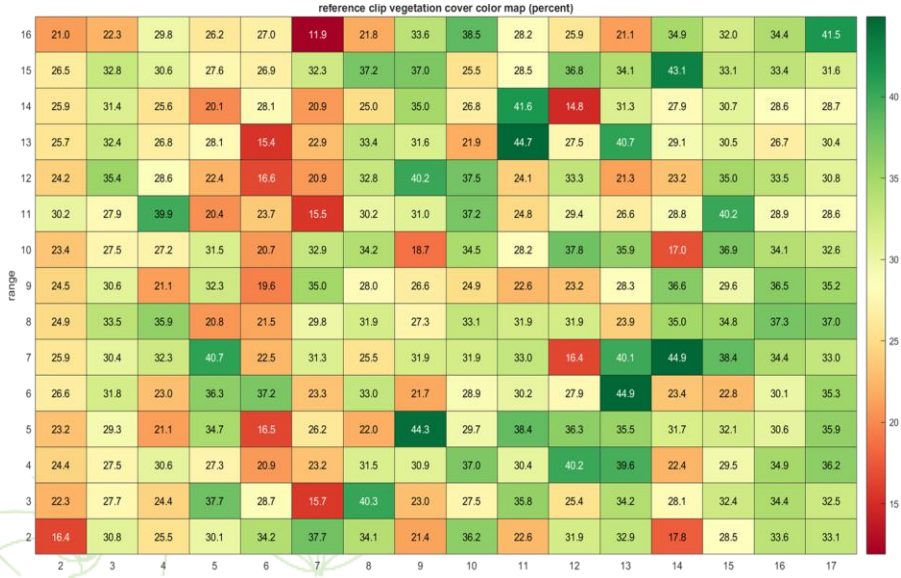
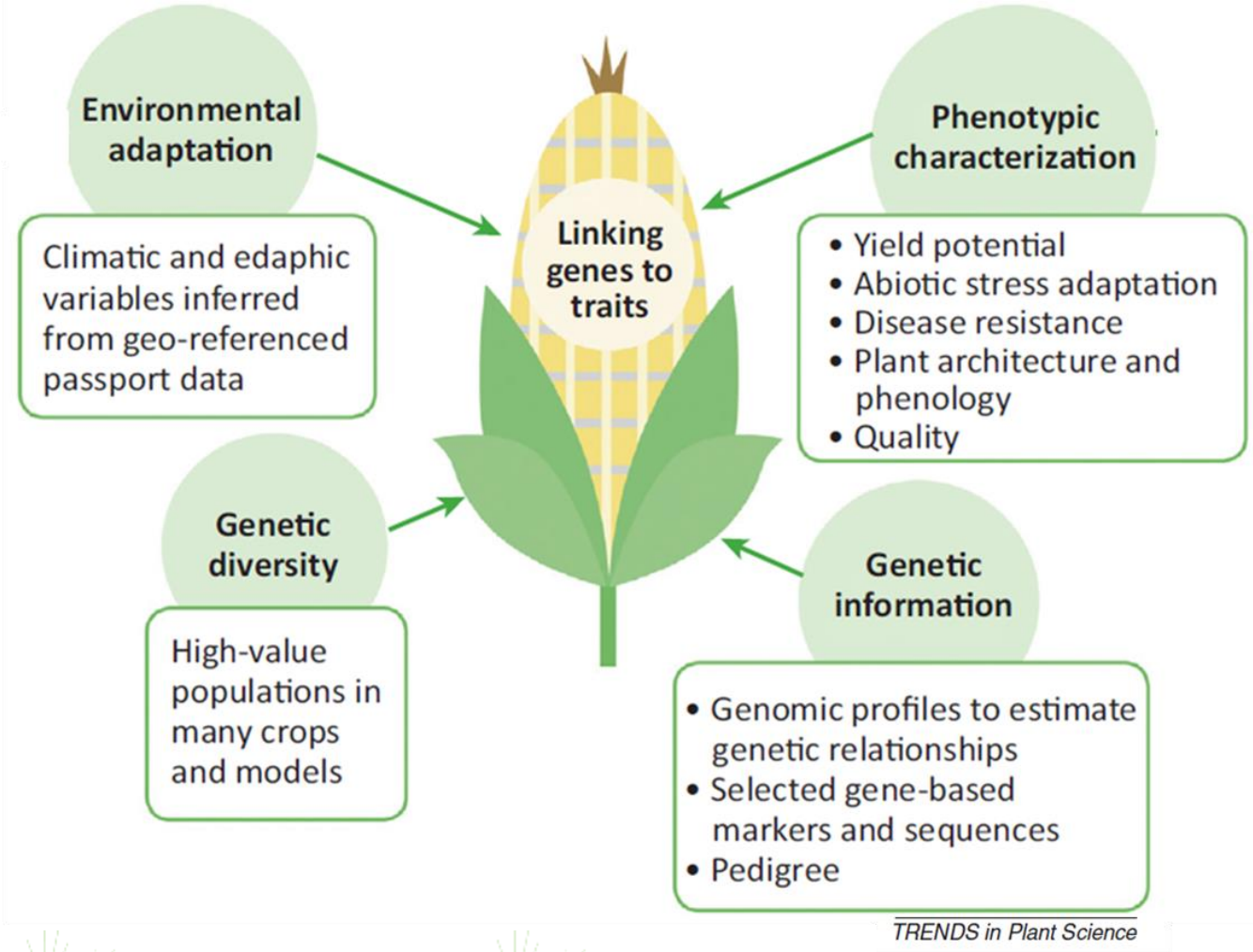
Advanced field-based phenotyping methods and opportunities for improving genetic gain in crop improvement





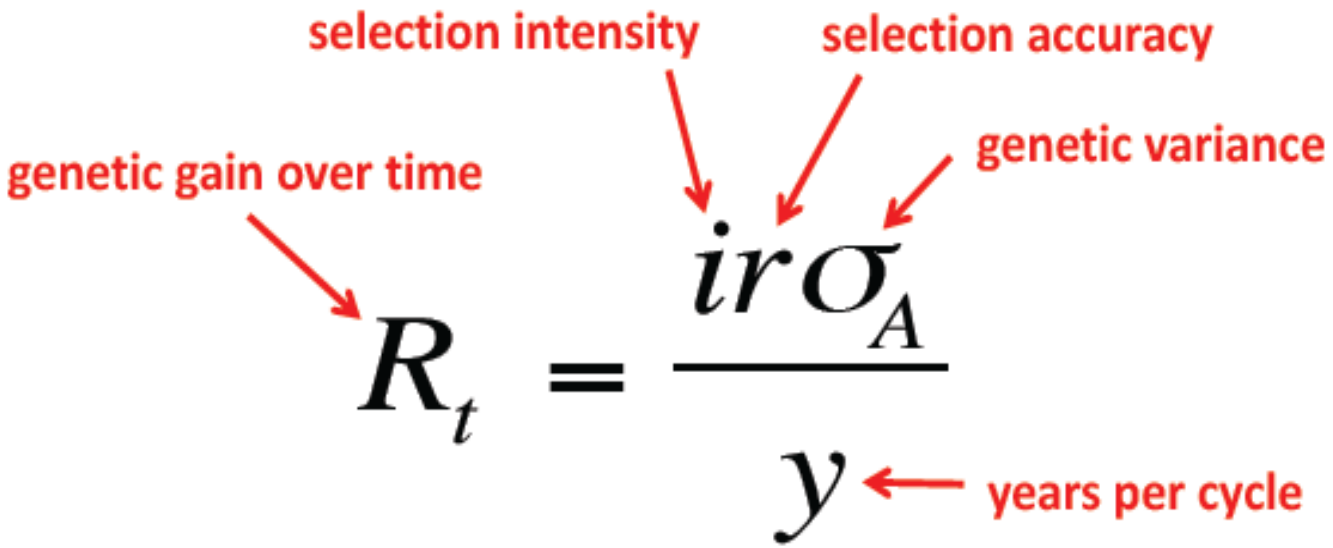
Pillars of crop breeding



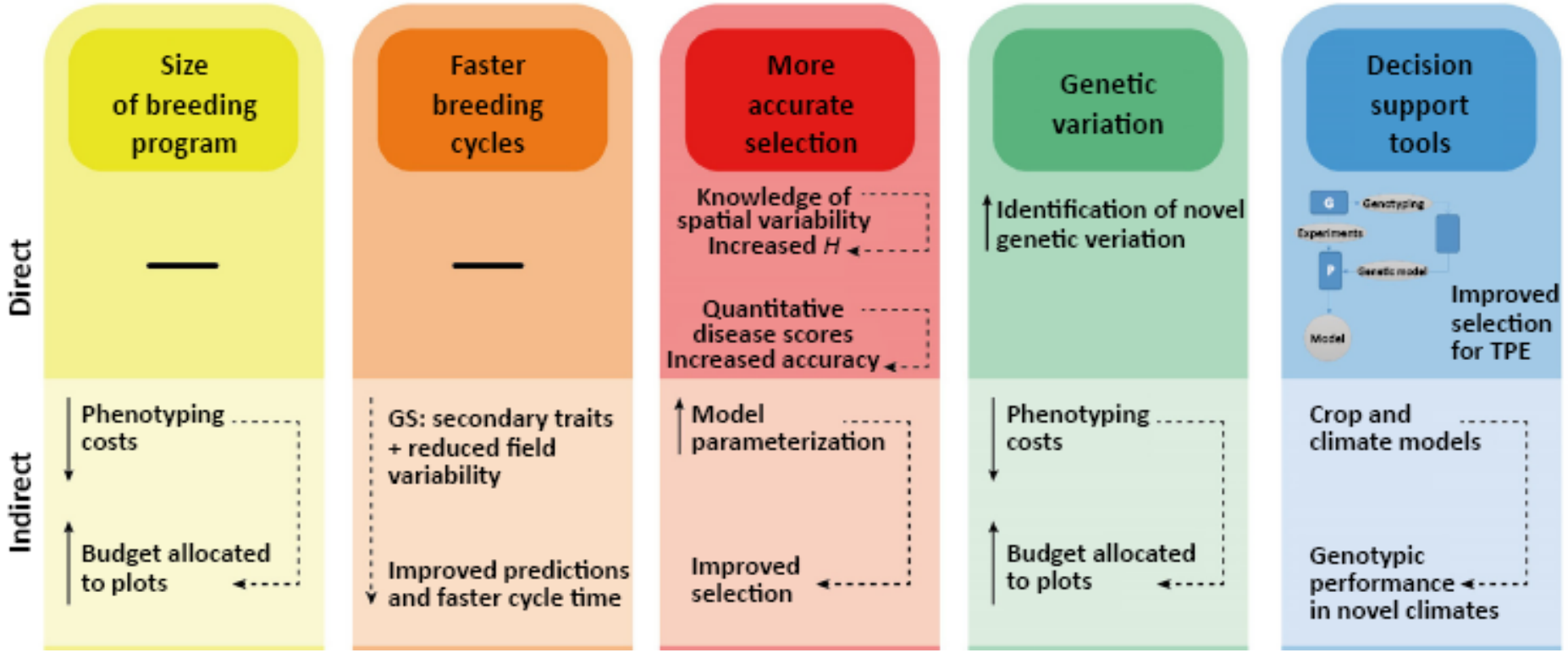
(Araus and Cairns 2014)

CIMMYT

Breeders Equation (Genetic gain)



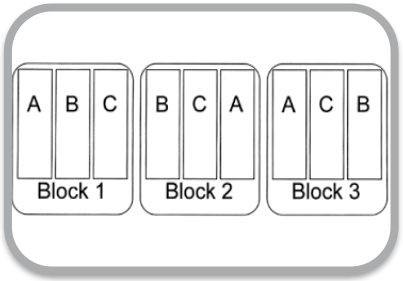
Pillars for increasing genetic gain



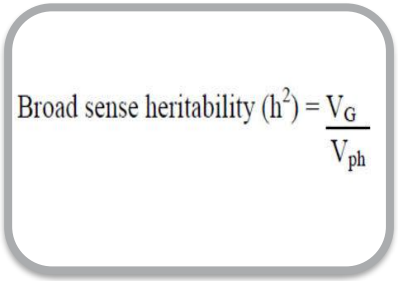
Key Field-based Phenotyping challenges

Monitoring all sources of field **environmental noise**

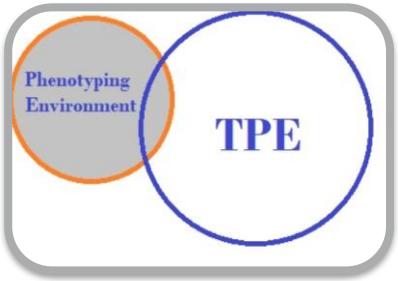
Growth **stage and granularity** at which phenotypes need to be gathered.



Combination of **statistical designs** and an appropriate data analysis framework



Heritability values high enough to sustain genetic progress in the TPE



A positive **genetic correlation** the phenotyping environment and the TPE.

Selection Accuracy

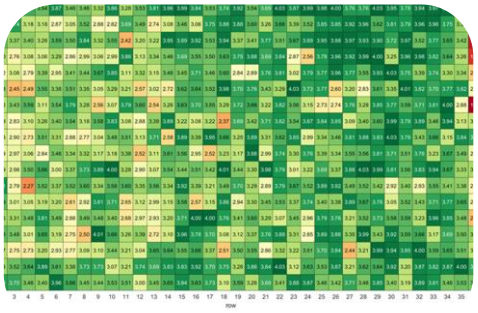
CIMMYT

Key Field-based Phenotyping challenges

Tracking spatial
Field variation

Stress quantification/
Monitoring

Data collection
methods



Plot quality
assessment

CIMMYT

$$R_t = \frac{ir\sigma_A}{y}$$

Field spatial variability mapping

i
selection intensity

r selection accuracy

y
cycle time

σ_A
genetic variability

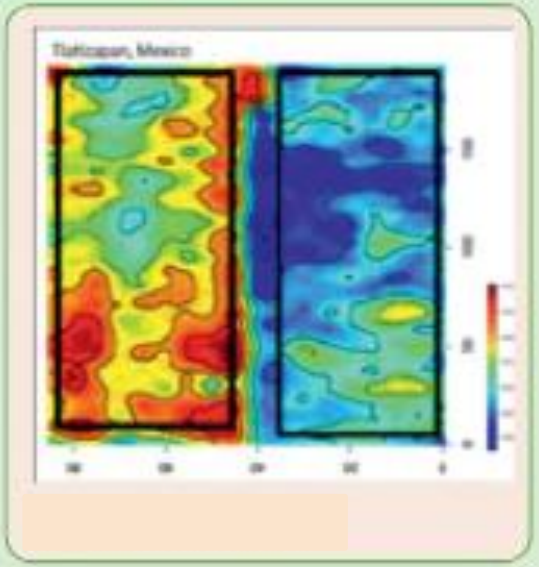
EM38 (1 ha = ~3 h)

Penetrometer (1ha = 3 days)

NDVI (1 ha = 1 day + 14–21 days to grow uniformity crop)

Reducing the effects of field variation

Identify field gradients, incorporate into field design



CIMMYT

$$R_t = \frac{ir\sigma_A}{y}$$

Field spatial variability mapping

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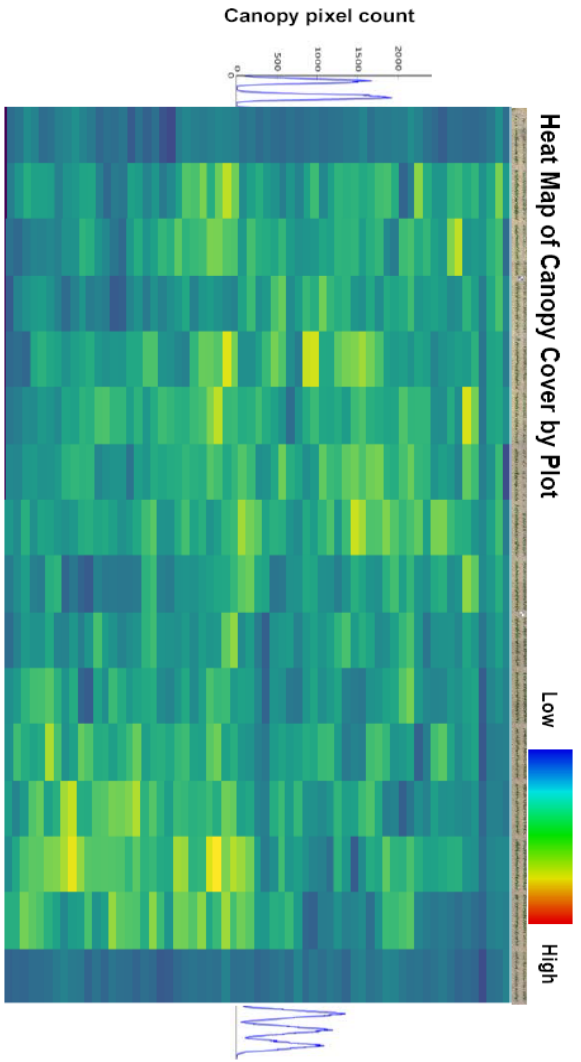

$$R_t = \frac{ir\sigma_A}{y}$$

Field spatial variability mapping

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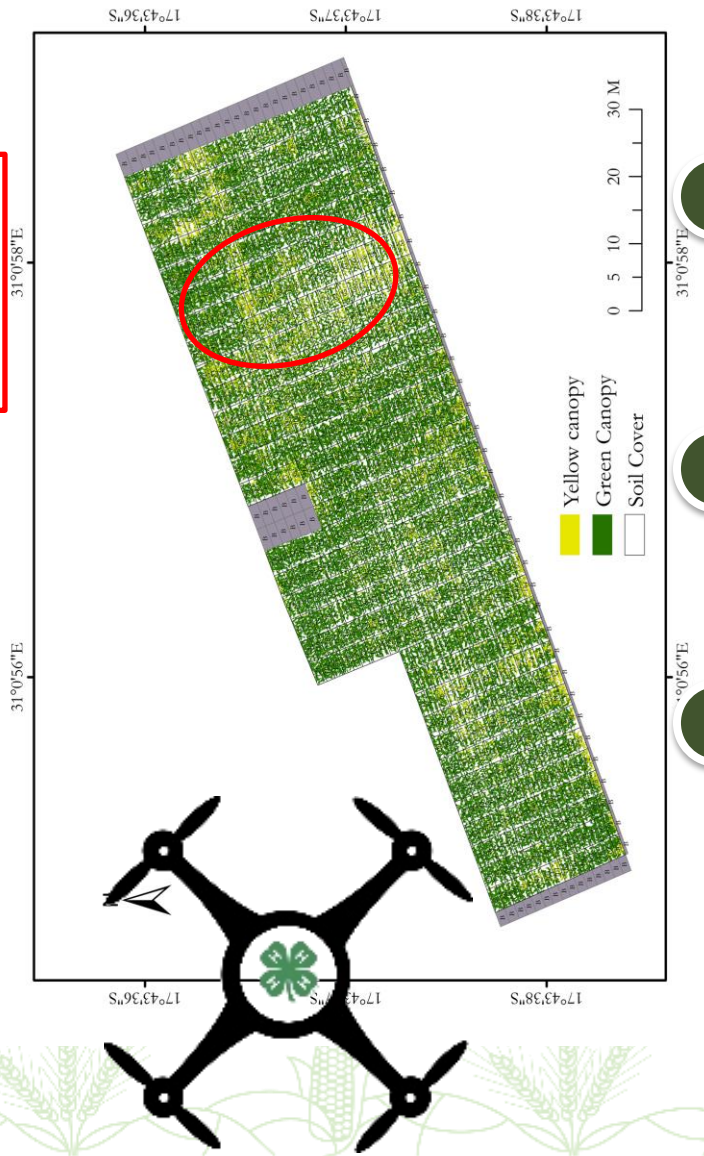

- **Controlling the variation**
- **Trial mapping**
- **Use for data analysis**

CIMMYT

$$R_t = \frac{ir\sigma_A}{y}$$

Field spatial variability mapping

i
selection intensity

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selection accuracy

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cycle time

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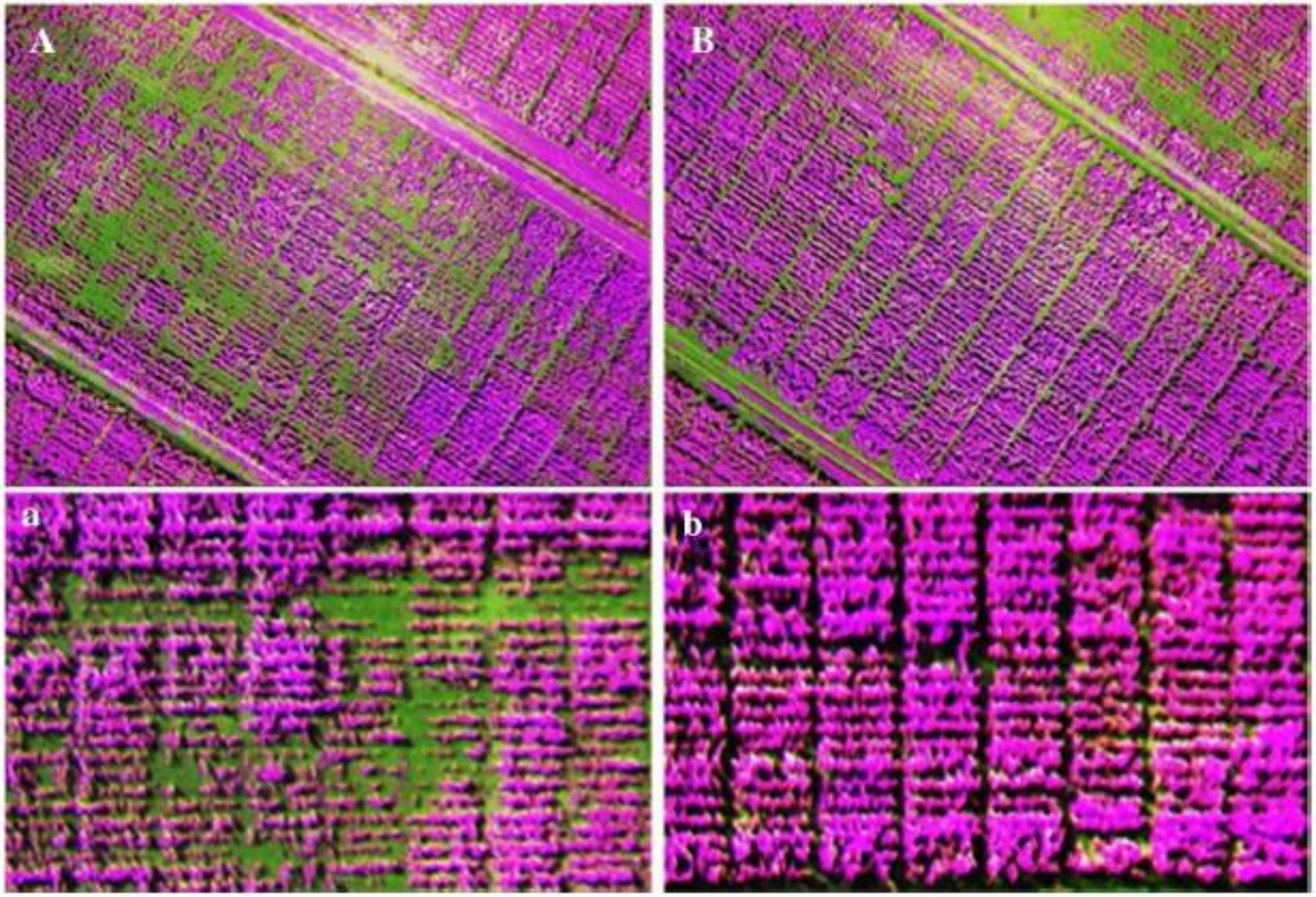
genetic variability

Controlling the variation



$$R_t = \frac{ir\sigma_A}{y}$$

Stress Monitoring/Quantification

i
selection intensity

r
selection accuracy

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cycle time

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genetic variability

Absolute yield level

About 3t/ha trial yield average

Yield reduction level

About 70% of yield under optimum conditions

Drought

Low Nitrogen

CIMMYT

$$R_t = \frac{ir\sigma_A}{y}$$

Stress Monitoring/Quantification

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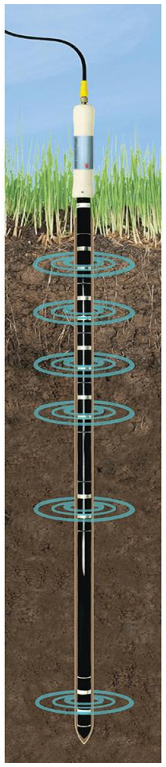
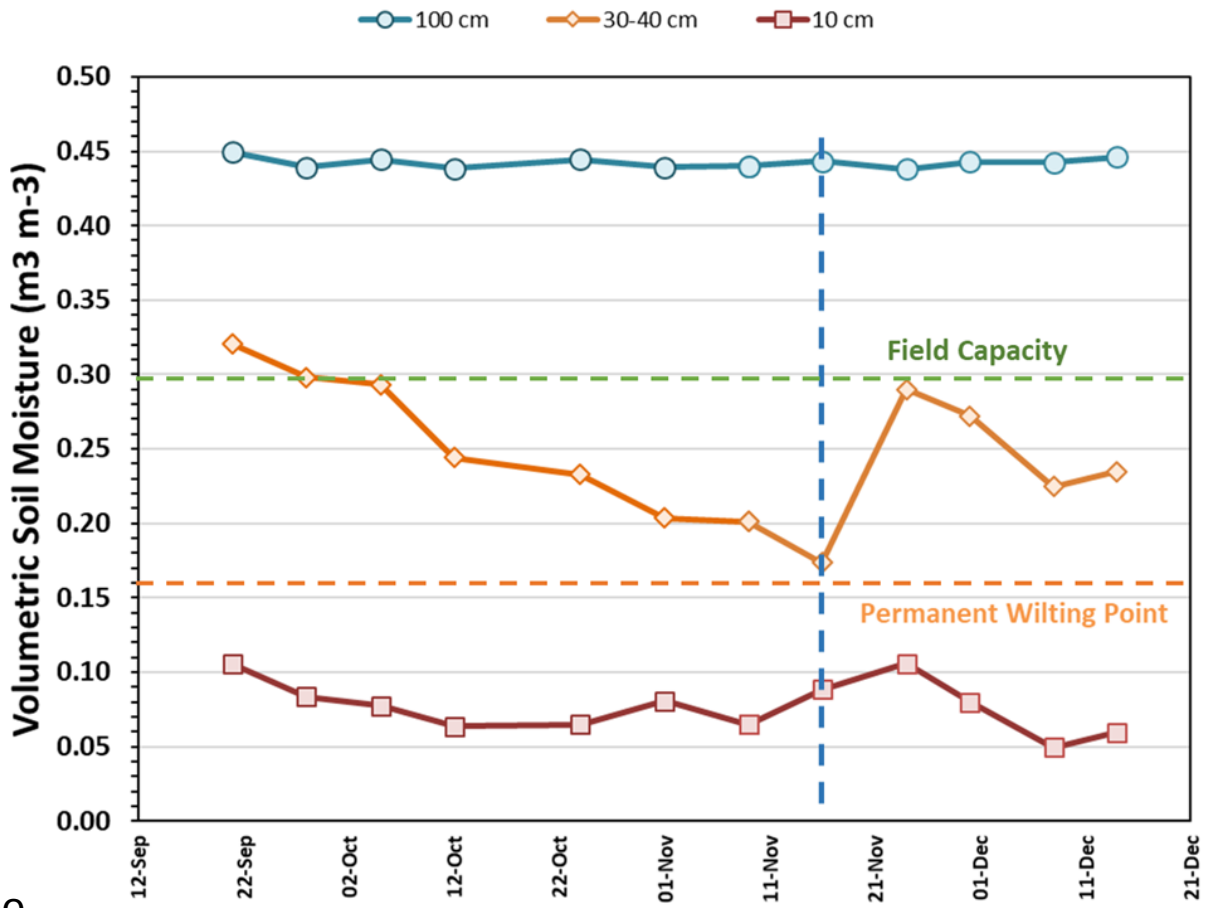


Capacitance probe PR2



CIMMYT

Timing of Stress Imposition

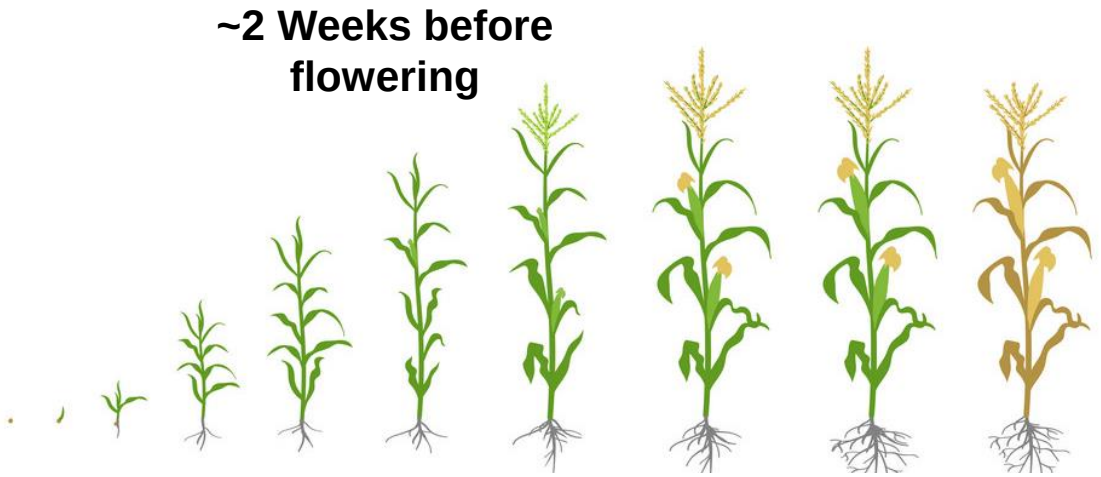
$$R_t = \frac{ir\sigma_A}{y}$$

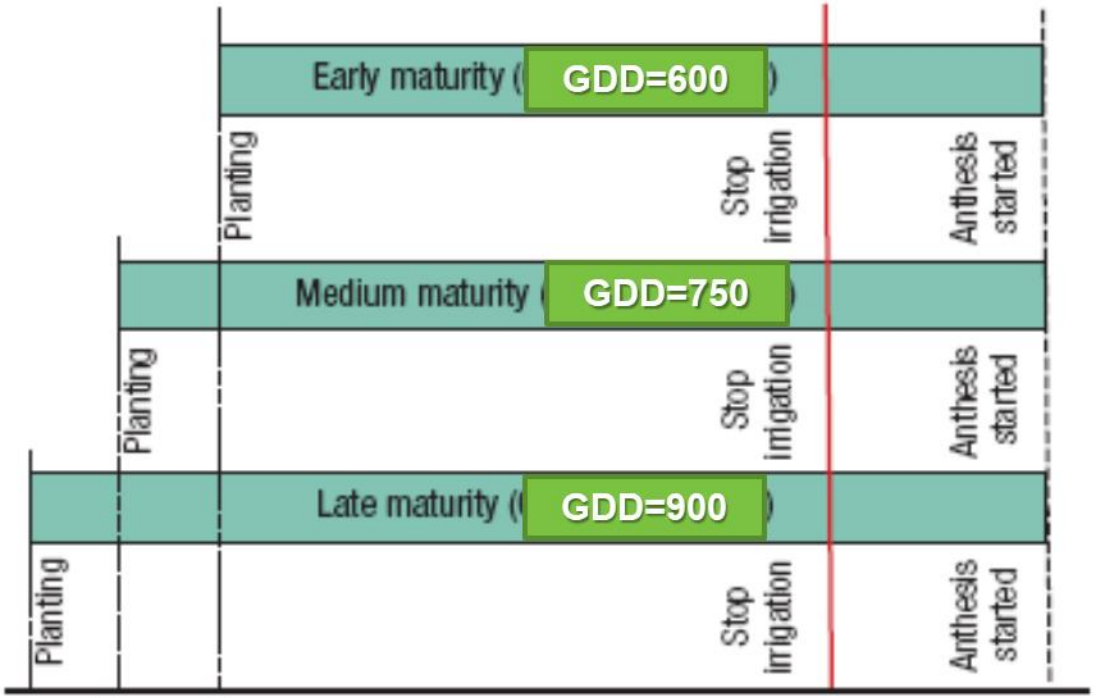
i
selection intensity

r
selection accuracy

y
cycle time

σ_A
genetic variability





$$R_t = \frac{ir\sigma_A}{y}$$

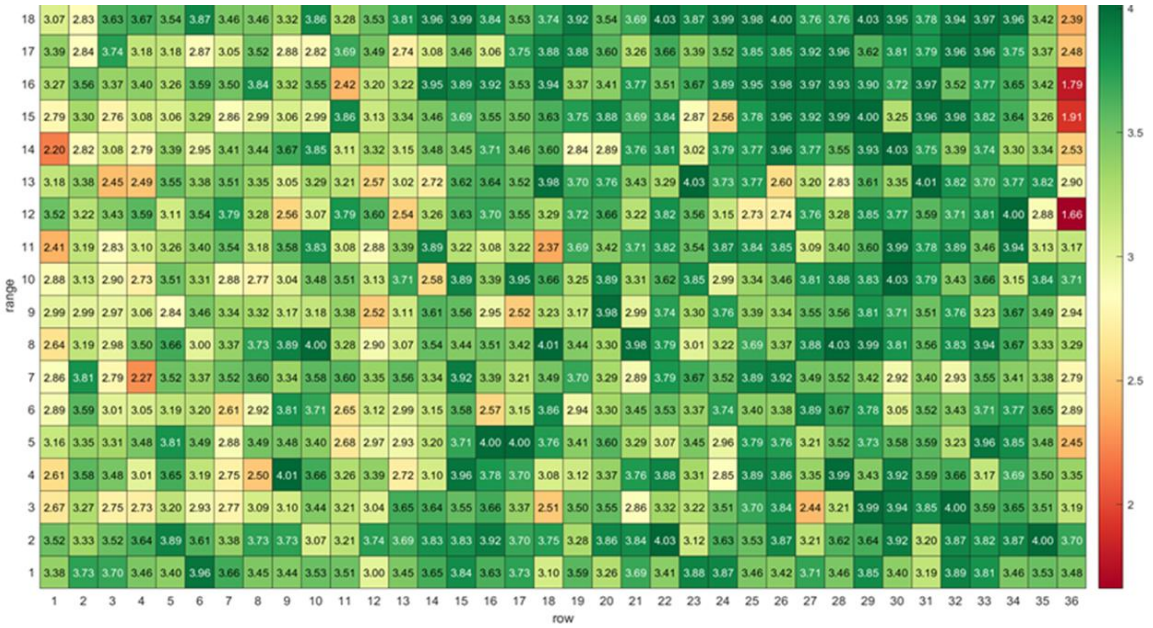
Plot quality assessment

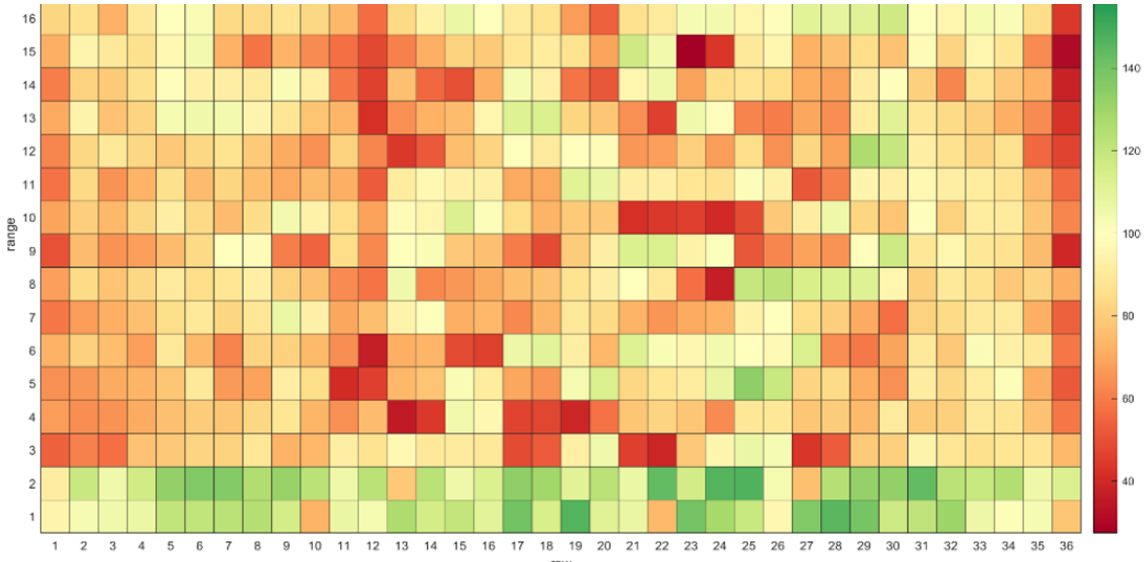
i
selection intensity

r
selection accuracy

y
cycle time

σ_A
genetic variability





$$R_t = \frac{ir\sigma_A}{y}$$

Reducing costs > increased selection intensity

i
selection intensity

r
selection accuracy

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σ_A
genetic variability

Data Collection methods

Field +
Trait measurement costs

Generation + management of larger populations

Selection intensity

CIMMYT

$$R_t = \frac{ir\sigma_A}{y}$$

Reducing costs > increased selection intensity

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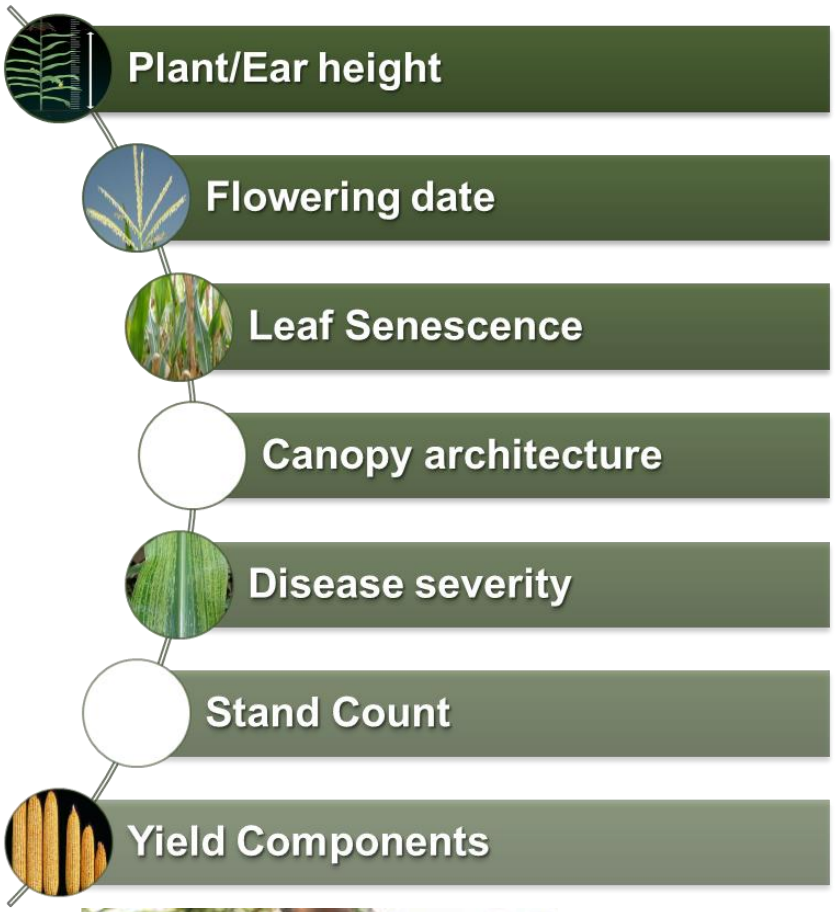

MYT

Visual scores VS image based data

$$R_t = \frac{ir\sigma_A}{y}$$

i
selection intensity

r
selection accuracy

y
cycle time

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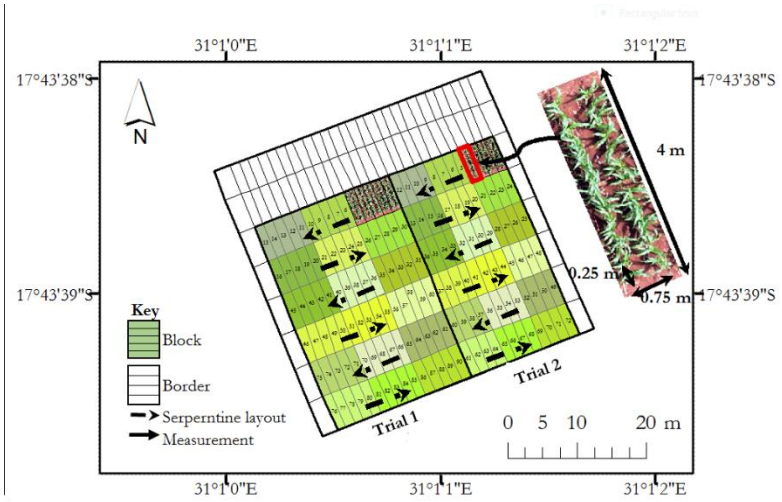
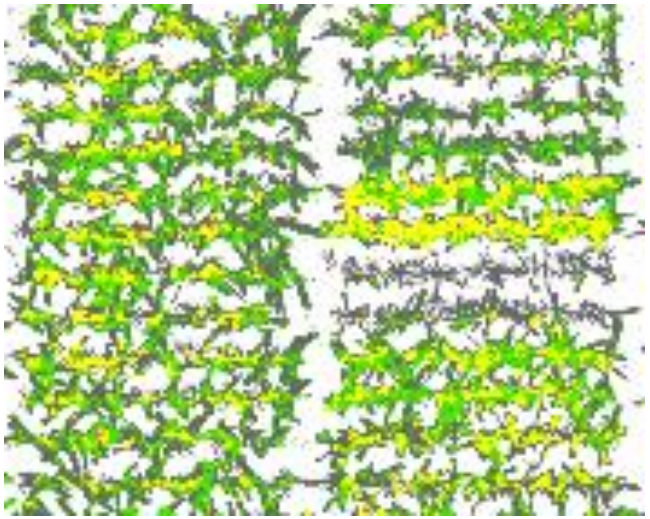
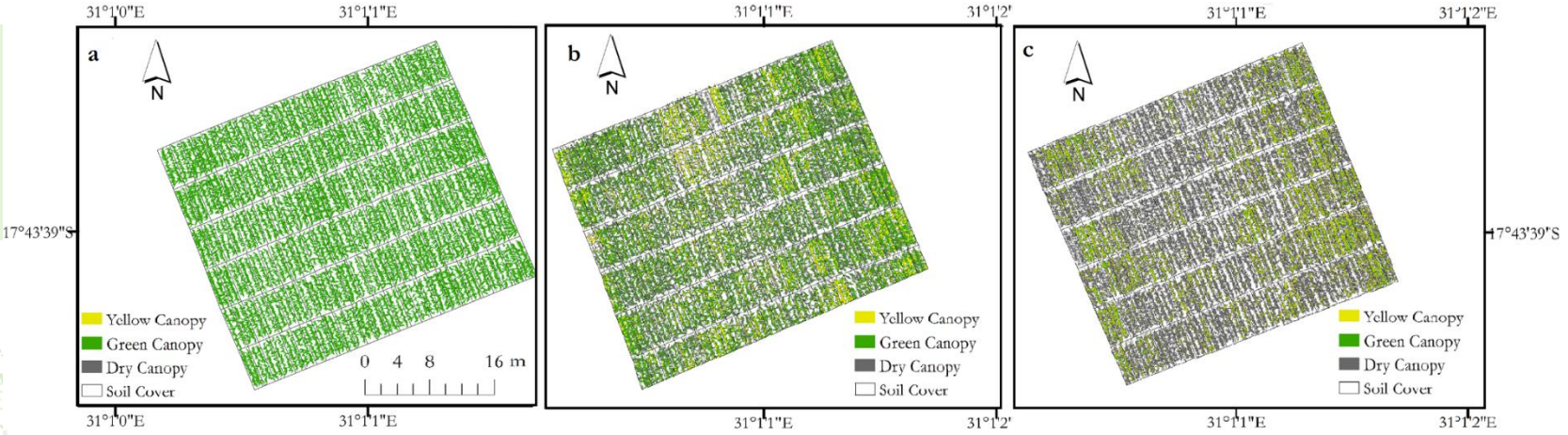
genetic variability





Low nitrogen field at CIMMYT-Harare (Zimbabwe)



$$R_t = \frac{ir\sigma_A}{y}$$

Visual scores VS image based data

i selection intensity

r selection accuracy

y cycle time

σ_A genetic variability

Canopy senescence

	Digital imaging	Visual assessment		
	Sen. index	Sen1 (%)	Sen2 (%)	Sen3 (%)
Heritability	**0.529**	**0.285**	**0.585**	**0.500**
Mean	**0.466**	**12.731**	**28.666**	**61.944**
Genetic correlation with yield	**-0.397****	**-0.179**	**0.006**	**-0.101**

CIMMYT

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Visual scores VS image based data

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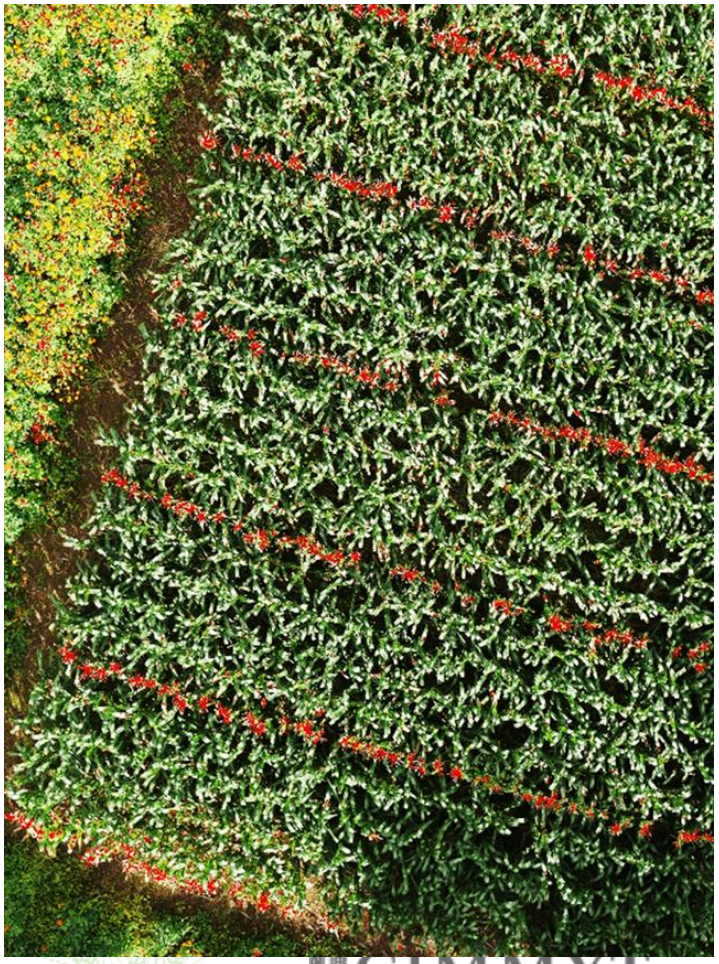

Manual measurements VS image based data

$$R_t = \frac{ir\sigma_A}{y}$$

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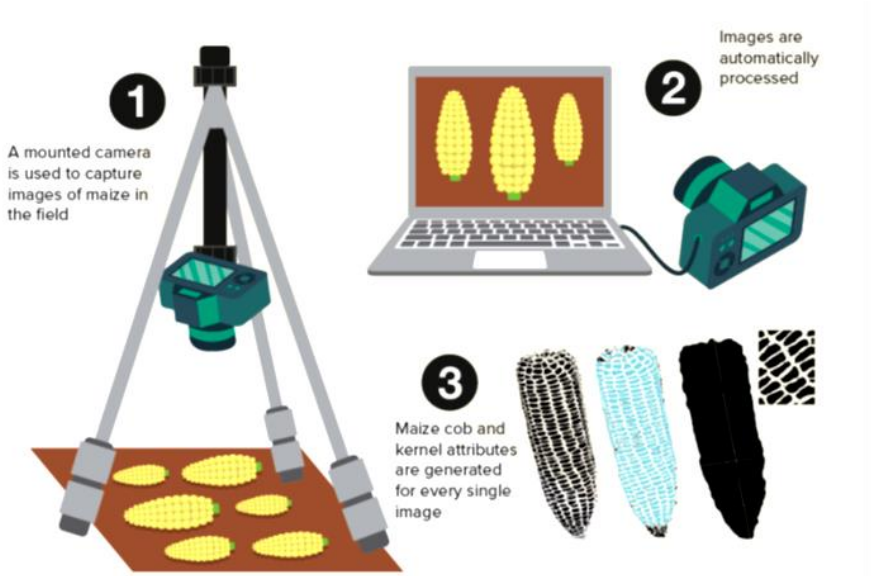

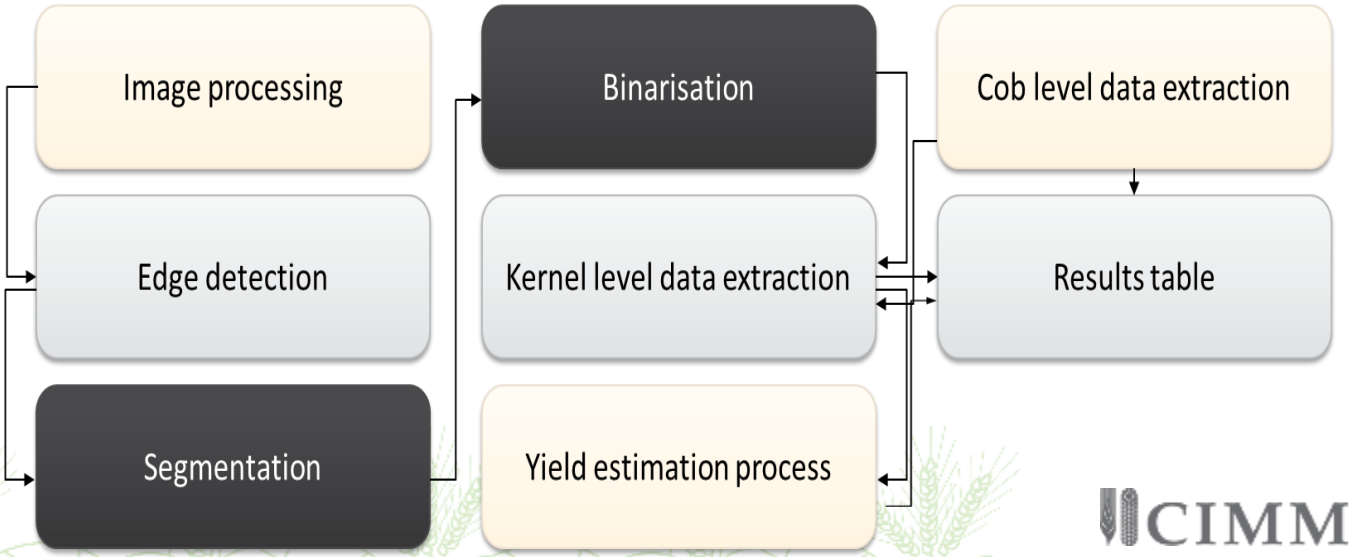

CIMMYT

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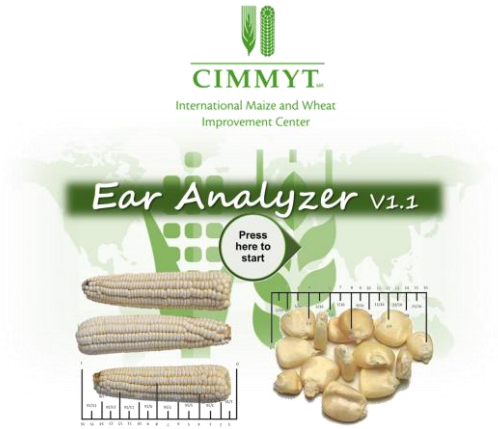
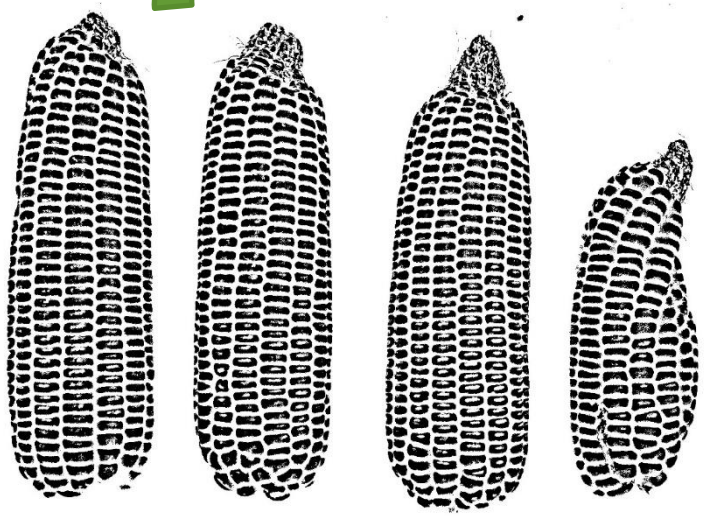


Image Analysis



- **Average cob size**
- **Cob number**
- **Cob uniformity index**
- **Total Kernel number**
- **Kernel row number**
- **Average kernel size**

$$R_t = \frac{ir\sigma_A}{y}$$

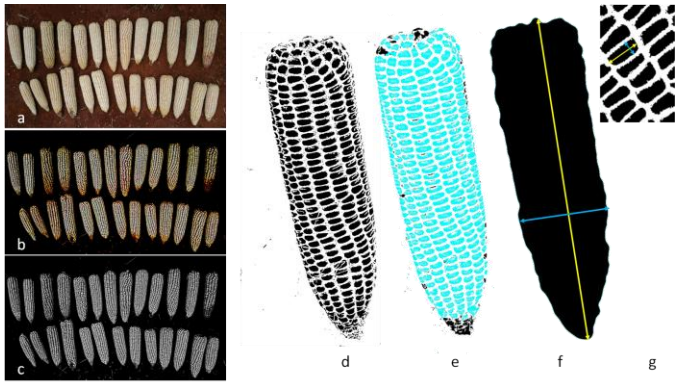
Manual measurements VS image based data

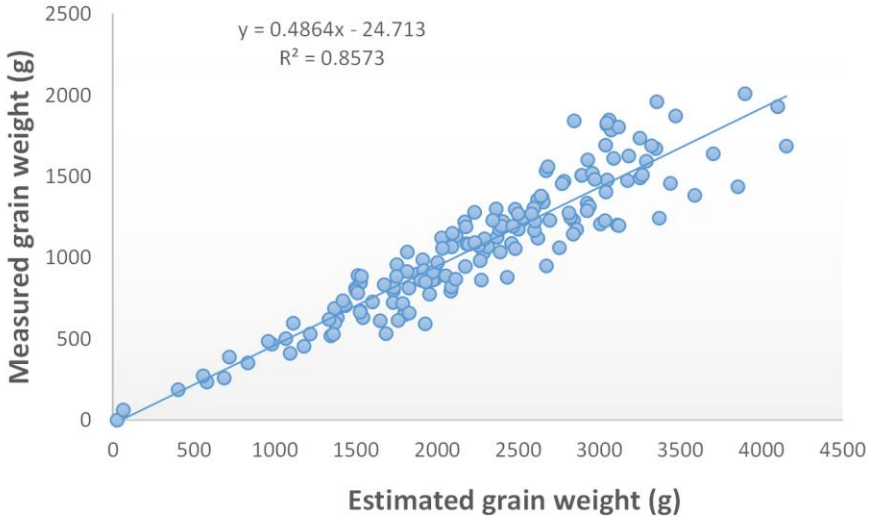
i selection intensity

r **selection accuracy**

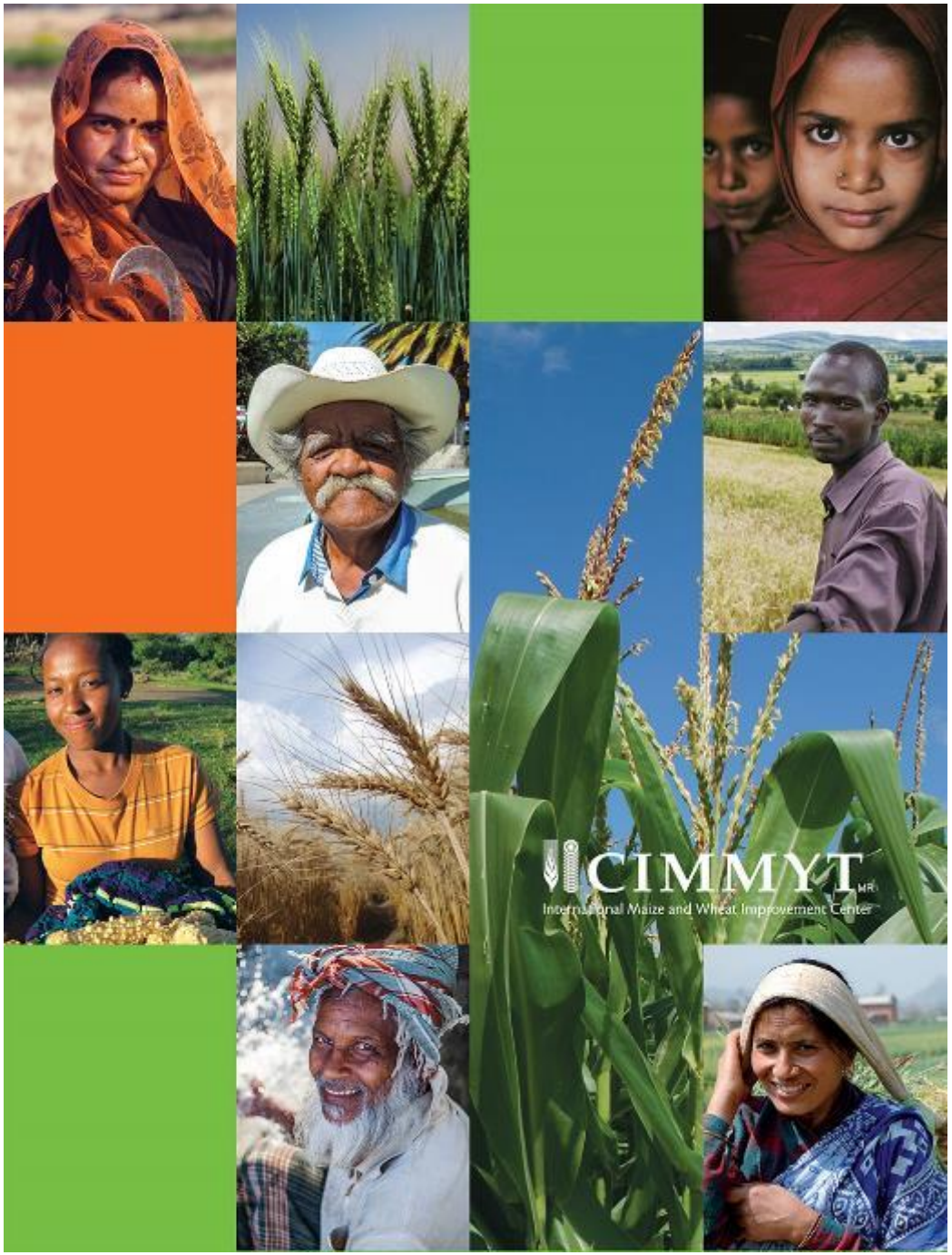
y cycle time

σ_A genetic variability





	Broad-sense heritability											
	Kernel attributes								Ear attributes			
Grain yield (Mg ha^{-1})	Visible Kernel Number	Mean width (cm)	Mean length (cm)	Total area (cm^2)	Mean area (cm)	Mean perimeter (cm)	Total Number per plot	Total Weight (g plot^{-1})		Number per plot	Mean length (cm)	Mean width (cm)
0.477	0.537	0.750	0.783	0.483	0.744	0.794	0.534	0.456		0.601	0.605	0.504



Thank you for your interest!