Effective and innovative approaches to phenotypic evaluation

Jill Cairns & Mainassara ZA

Global Maize Program

CIMMYT

Outline

1. The role of phenotyping

2. Conceptual scheme

3. Phenotyping for cultivar development – shift from “physiologist preferred traits” to “breeder preferred traits”

4. Devising an effective “screen” for a trait of interest

5. Phenotyping technologies

6. Data collection, data management, data analysis

7. Phenotyping in the context of genetic gain

8. Phenotyping and product profiles

Role of Phenotyping

(Adapted from Jesse Poland)

Role of Phenotyping

Basis for understanding of traits

Molecular and biochemical signatures

"observable" or "measurable" properties of an organism

Toolbox

Set of methodologies and protocols

Evaluation

Generate information

Understand plant-environment interactions

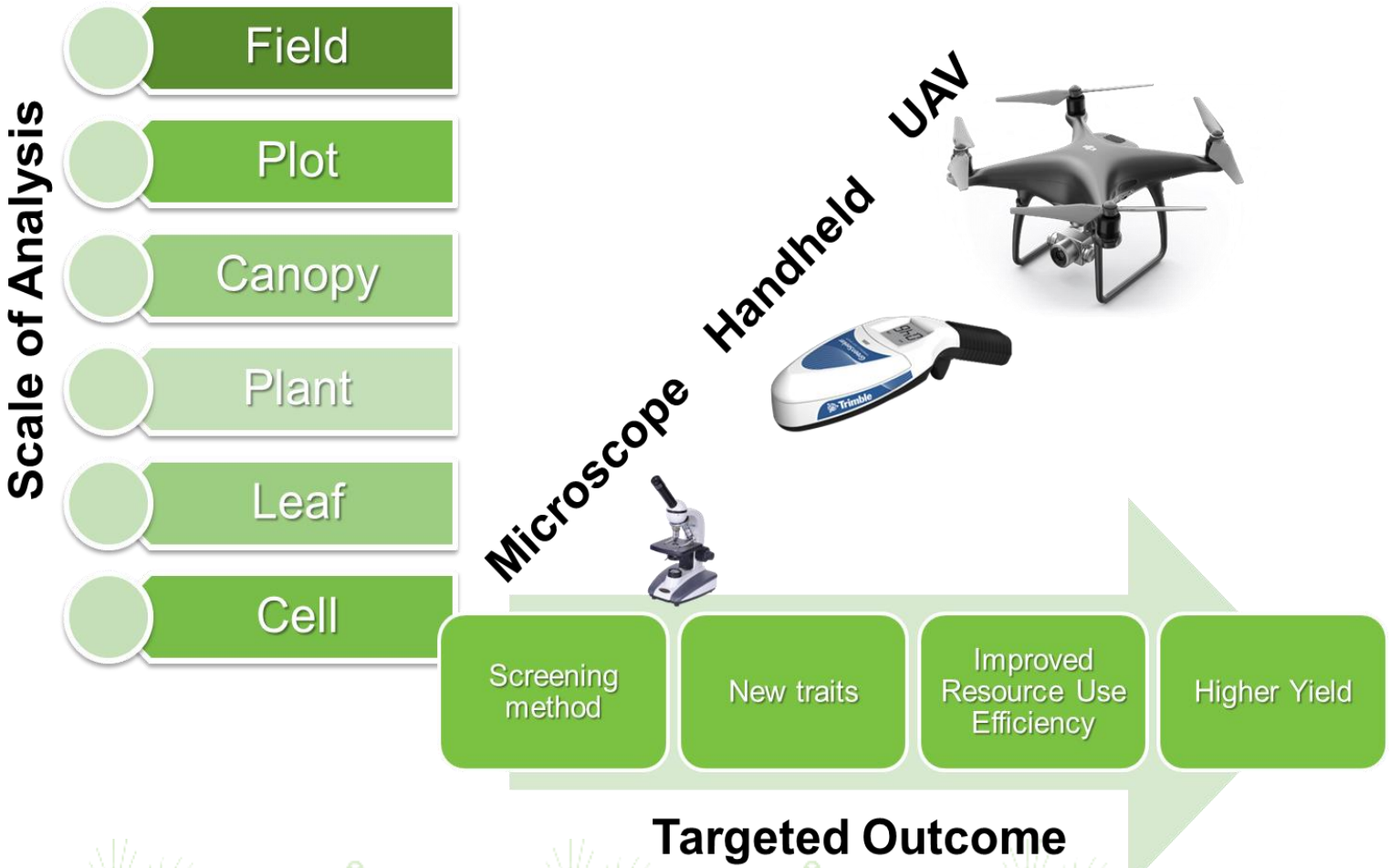
Understanding of how crops function

Selection for desirable traits

Crop models calibration

CIMMYT

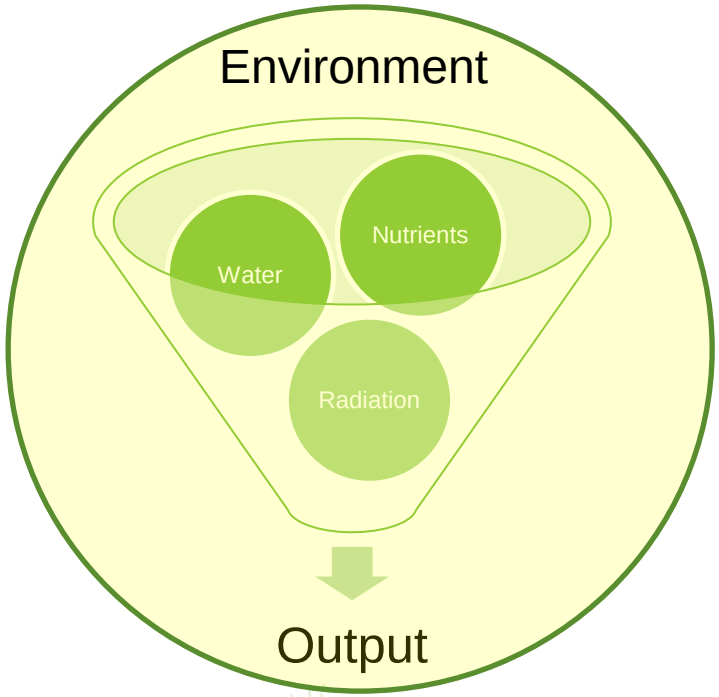
Conceptual Scheme



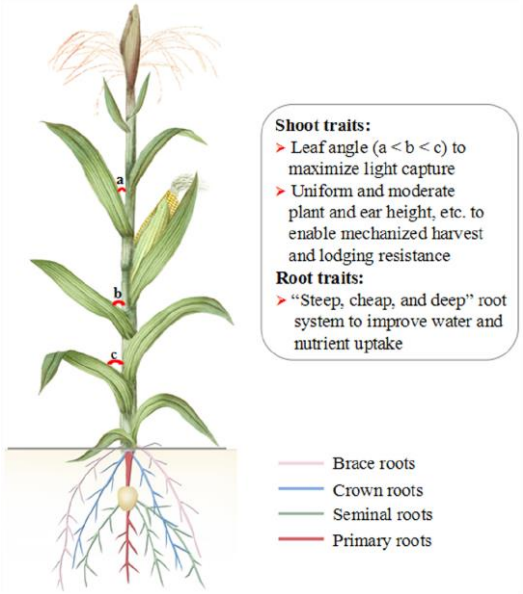
CIMMYT

Devising an effective “screen” for a trait of interest

Trait Characterization



- Variation?
- Proxies?
- Mechanism involved?
- What to select for?



CIMMYT

Devising an effective “screen” for a trait of interest

Trait Characterization

Drought tolerance

CIMMYT

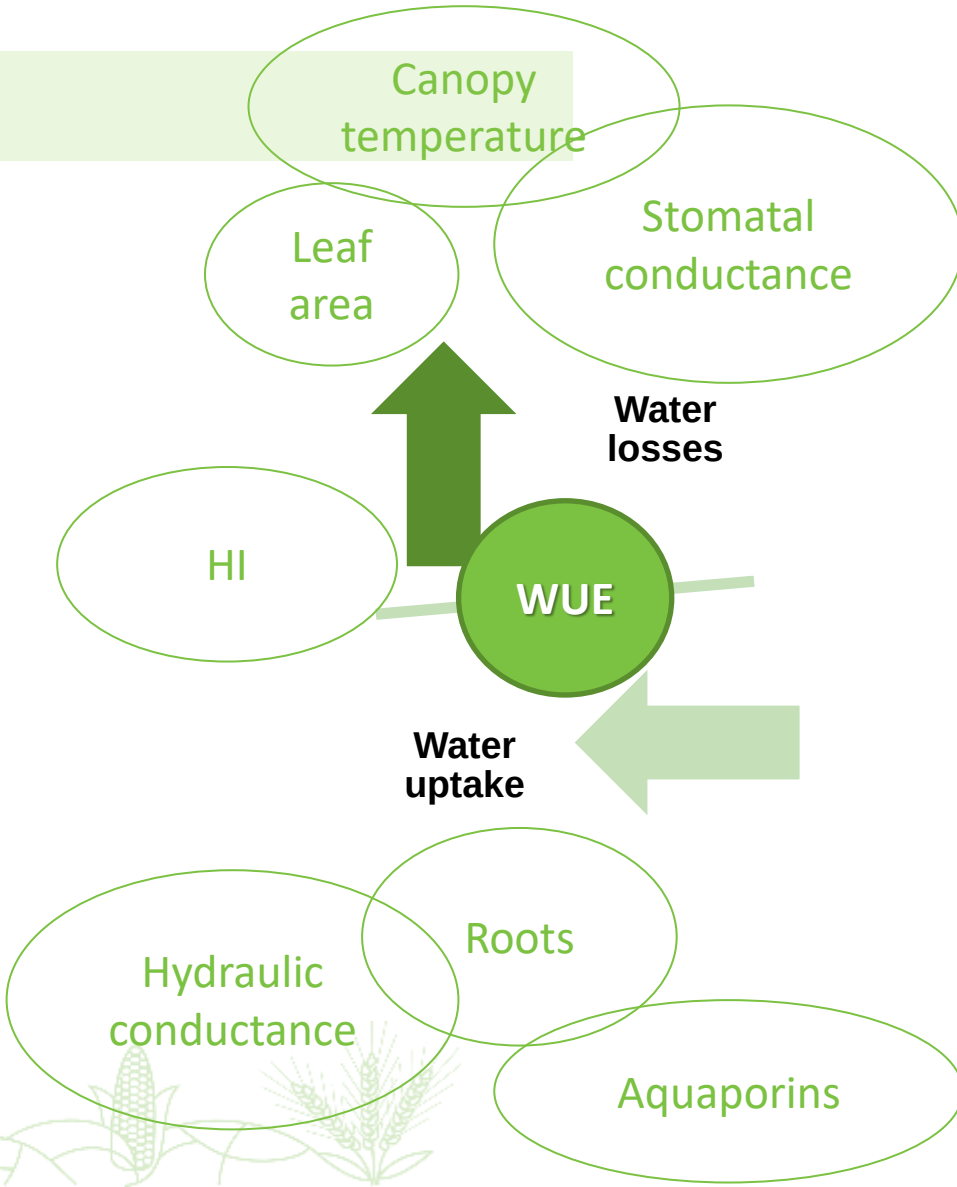
Devising an effective “screen” for a trait of interest

Trait Characterization

Drought tolerance

GY = [W x Ptrans x WUE] x HI

where
W = water available to the plant
Ptrans= proportion of water transpired by the crop
WUE = water use efficiency
HI = harvest index



Devising an effective “screen” for a trait of interest

Trait Characterization

Low nitrogen tolerance

CIMMYT

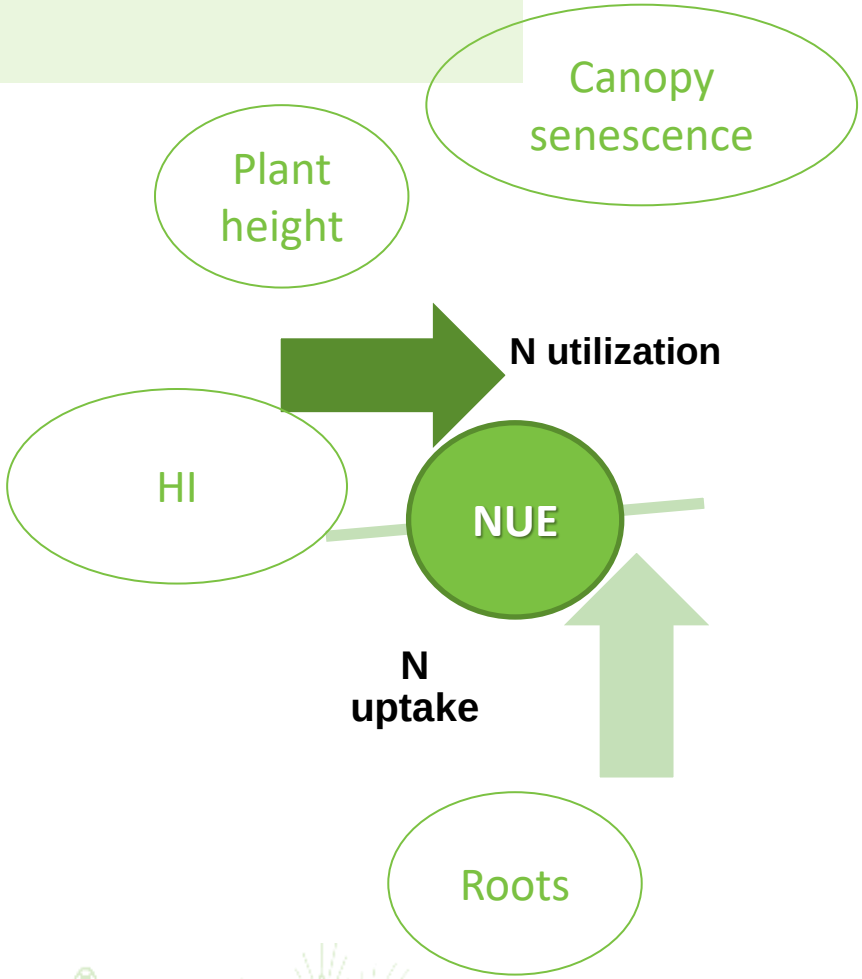
Devising an effective “screen” for a trait of interest

Trait Characterization

Nitrogen use efficiency

GY = [NA x Nuptake x NUE] x HI

where
NA = soil N available to the plant
Nuptake= proportion of N taken up by the crop
NUE = nitrogen use efficiency
HI = harvest index



CIMMYT

Devising an effective “screen” for a trait of interest

Trait Characterization

Yield potential

Devising an effective “screen” for a trait of interest

Trait Characterization

Yield potential

GY = RAD x %RI x GLD x RUE x HI

where

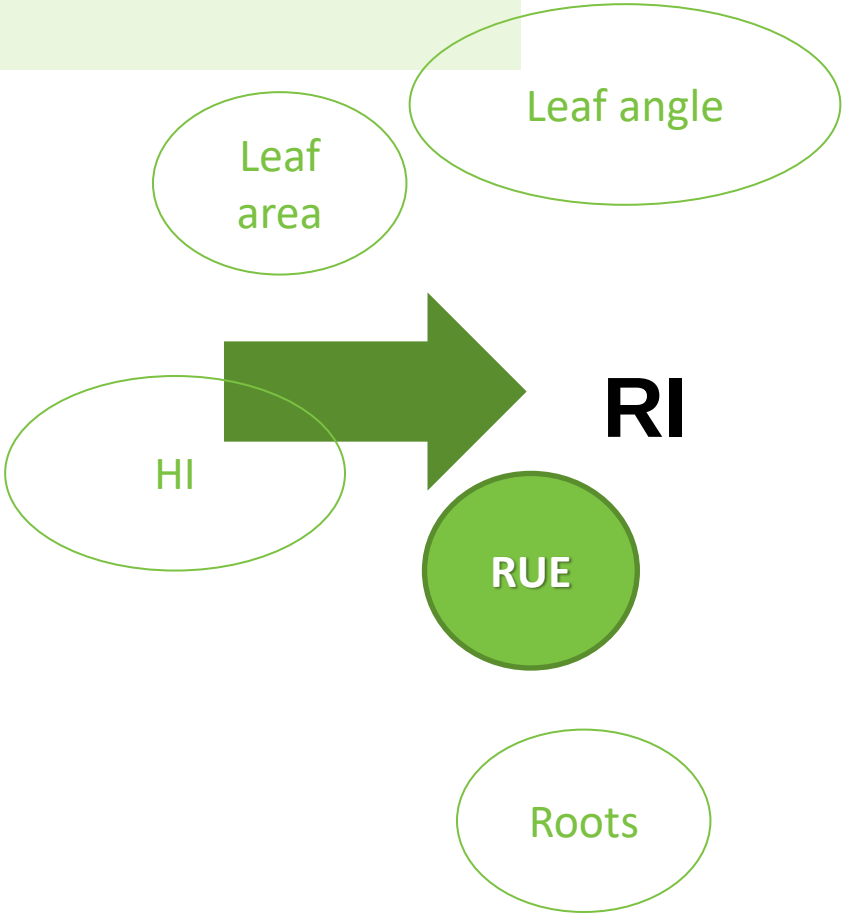
RAD = incident radiation per day

%RI = fraction of incident radiation intercepted by green leaves

GLD = green leaf duration, or number of days leaves remain green

RUE = radiation use efficiency

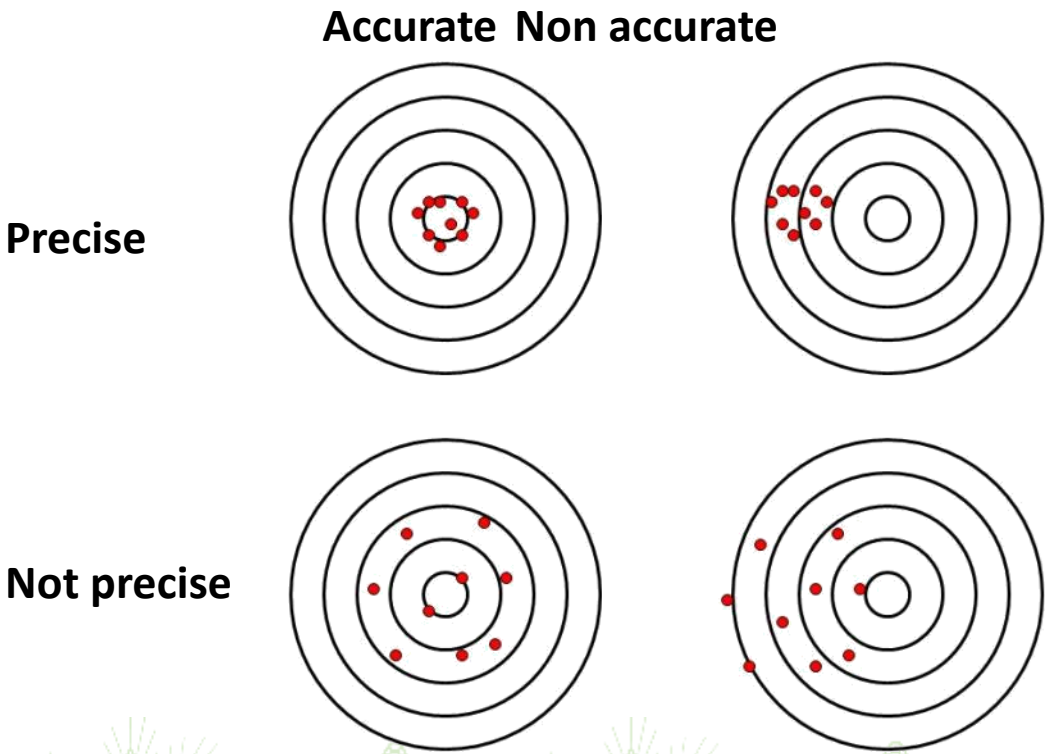
HI = harvest index



CIMMYT

Devising an effective “screen” for a trait of interest

Precision and accuracy in phenotyping



Precision does not necessarily mean reliability/accuracy

Devising an effective “screen” for a trait of interest

Precision and accuracy in phenotyping

Precision

Precision management (Stress…..)

Environment Characterization

Data collection methods/tools

CIMMYT

Devising an effective “screen” for a trait of interest

Precision and accuracy in phenotyping

Accuracy

Rep. of TPEs

Relevant treatment

Timing of data collection

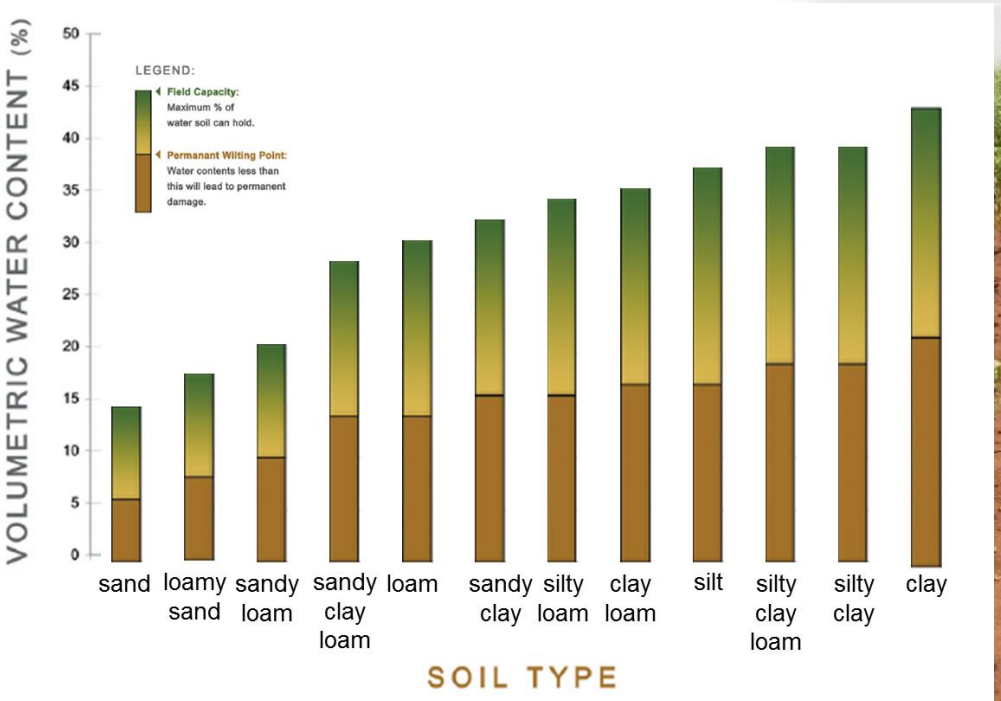
CIMMYT

Devising an effective “screen” for a trait of interest

Testing environments: specialized vs non-specialized

Basic requirements

Site selection criteria



Devising an effective “screen” for a trait of interest

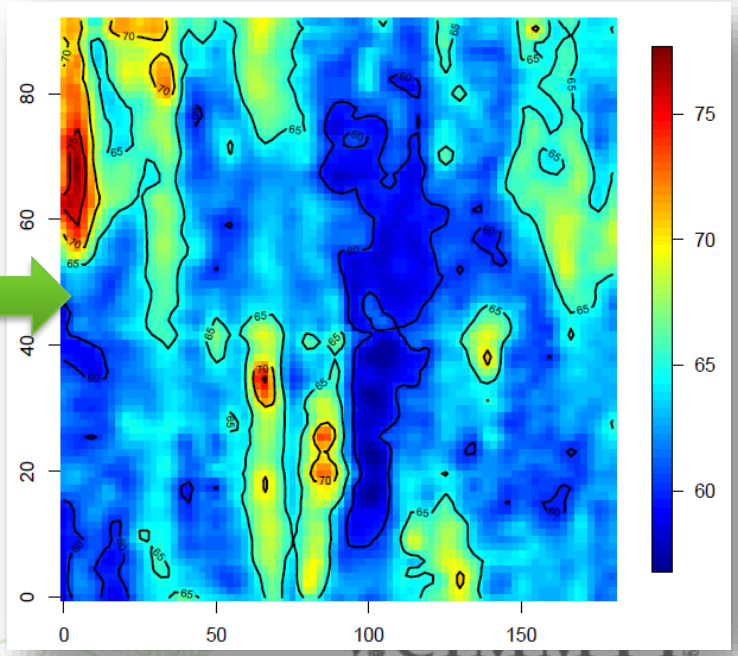
Testing environments: specialized vs non-specialized

Basic requirements

Mapping spatial variability

Quantification of biomass

- Visual estimates
- Image analysis
- Spectral reflectance



Devising an effective “screen” for a trait of interest

Testing environments: specialized vs non-specialized

Uniformity trials

Uniformity trial can significantly improve characterization of germplasm:

- *reduce the risk of failure*
- *plot error control*
- *accurate stress management*
- *improve data quality*

CIMMYT

Devising an effective “screen” for a trait of interest

Testing environments: specialized vs non-specialized

Uniformity trials

Uniformity trial can significantly improve characterization of germplasm:

- *reduce the risk of failure*
- *plot error control*
- *accurate stress management*
- *improve data quality*

CIMMYT

Devising an effective “screen” for a trait of interest

Testing environments: specialized vs non-specialized

Specialized Vs Non-Specialized

- Managed Drought
- Random Stress
- Managed Low Nitrogen
- On-Farm

CIMMYT

Devising an effective “screen” for a trait of interest

Testing environments: specialized vs non-specialized

Specialized Vs Non-Specialized

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
CIMMYT.

PHENOTYPING FOR ABIOTIC STRESS TOLERANCE IN MAIZE:
HEAT STRESS
P.H. Zaidi, M. Zaman-Allah, S. Trachsel, K. Seetharam, J.E. Cairns and M.T. Vinayan
CIMMYT.

PHENOTYPING FOR ABIOTIC STRESS TOLERANCE IN MAIZE:
WATERLOGGING STRESS
P.H. Zaidi, M.T. Vinayan and K. Seetharam
CIMMYT Asia Maize Program, Hyderabad, India
CIMMYT.

http://excellenceinbreeding.org/sites/default/files/manual/58000_4.pdf

IMMYT

Phenotyping technologies

Platforms and tools

Classical phenotyping methods were:

- labor intensive/slow with associated cost and precision/accuracy implications

- limited by their throughput which impacted the number of traits that can be evaluated.

Phenotyping technologies

Platforms and tools

Phenomics is going through a phase of rapid development

Robotic measurements

Remote sensing

CIMMYT

Phenotyping technologies

Platforms and tools

Phenotyping technologies

Platforms and tools

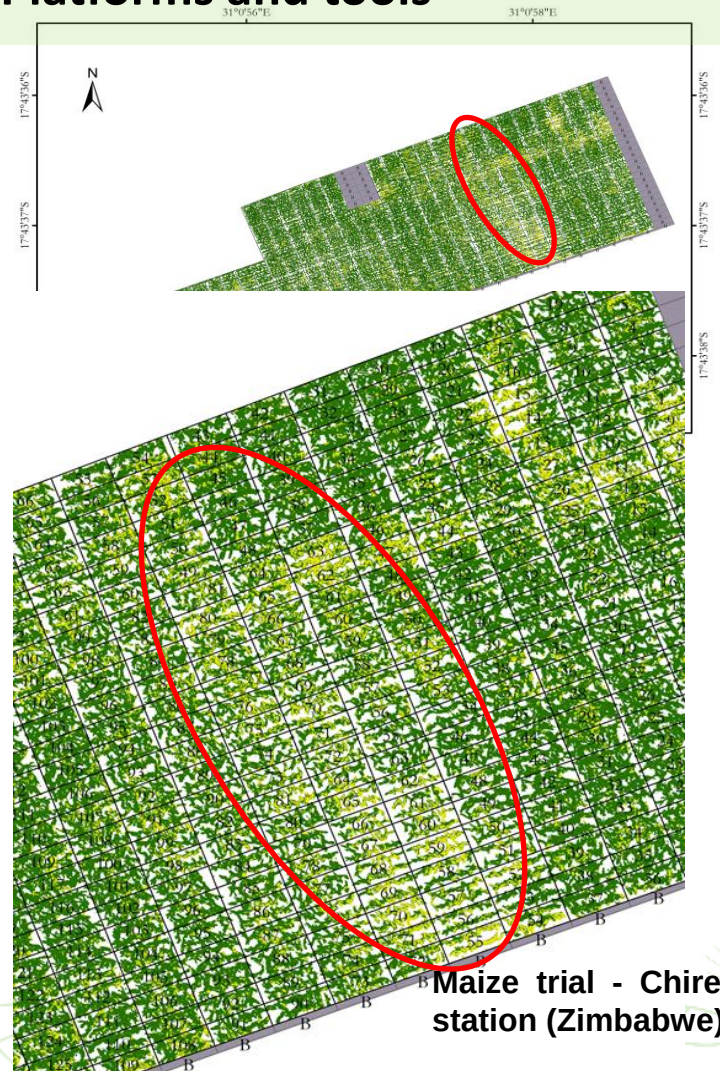
CIMMYT

Phenotyping technologies

Platforms and tools

Phenotyping technologies

Platforms and tools



Maize trial - Chiredzi station (Zimbabwe)

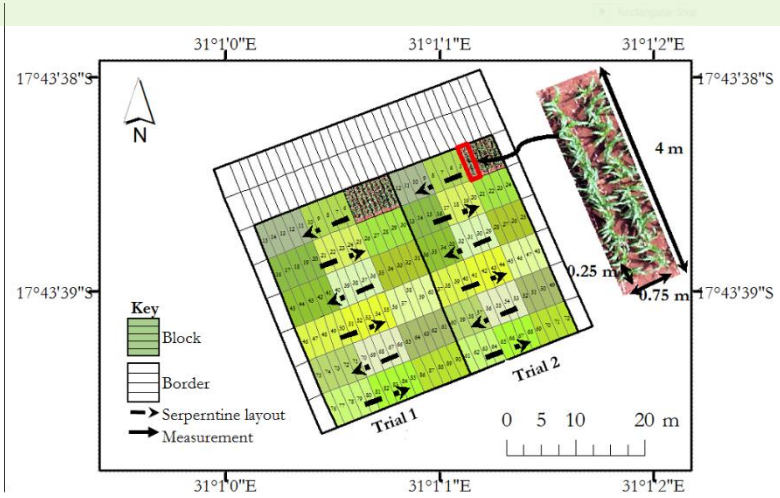
Field Variability Mapping

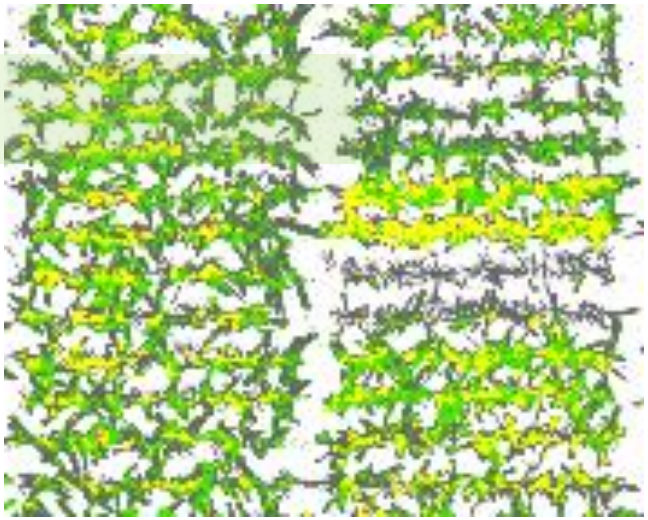
- Controlling field spatial variation
- Trial mapping
- Potential use for data analysis

CIMMYT

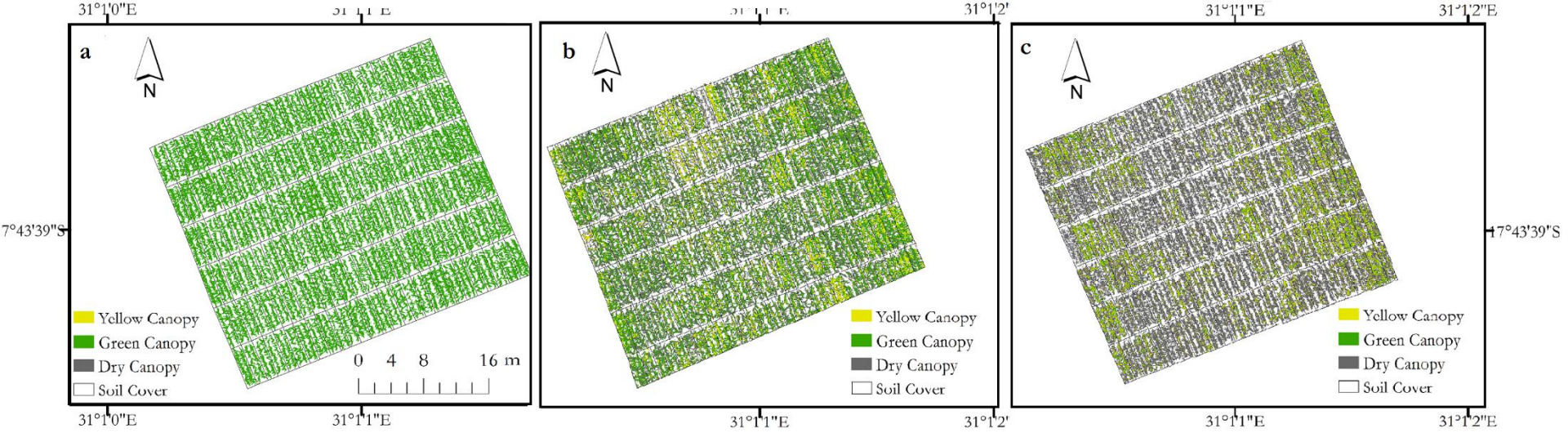
Phenotyping technologies

Platforms and tools





Low nitrogen field at CIMMYT-Harare (Zimbabwe)



Phenotyping technologies

Platforms and tools

	Canopy			Total Cover	RGC	Grain Yield (Mg ha^{-1})
	Yellow	Dry	Green			
Heritability	0.526	0.766	0.544	0.602	0.547	0.547
Mean	1.625	0.376	2.379	0.660	0.358	1.670
Genetic correlation (ρ_g)	0.602**	-0.301*	0.616***	0.792***	0.650***	-
n Trials	10	10	10	10	10	10

CIMMYT

Phenotyping technologies

Platforms and tools

Male flowering

- Tassel development detection

- Actual anthesis date requires integration of machine learning

Phenotyping technologies

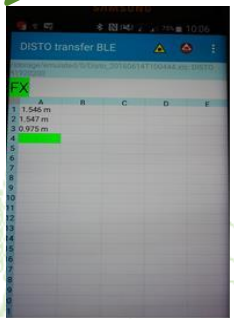
Platforms and tools

SENSORS	APPLICATIONS
Thermal Imaging	Leaf and canopy temperature
RGB and Morphometric Imaging	Shoot biomass, growth dynamics, shoot shape, color index, …
3D Scanning	Shoot structure, leaf angle distribution, shoot biomass
Kinetic Chlorophyll Fluorescence Imaging	Photosynthetic status, quantum yield, non-photochemical quenching, electron transport rate, …
Hyperspectral Imaging	Pigment composition, biochemical compounds, nitrogen content, leaf water status, …
Near-InfraRed (NIR) Imaging	Leaf and canopy water status

Phenotyping technologies

Platforms and tools

Plant Height



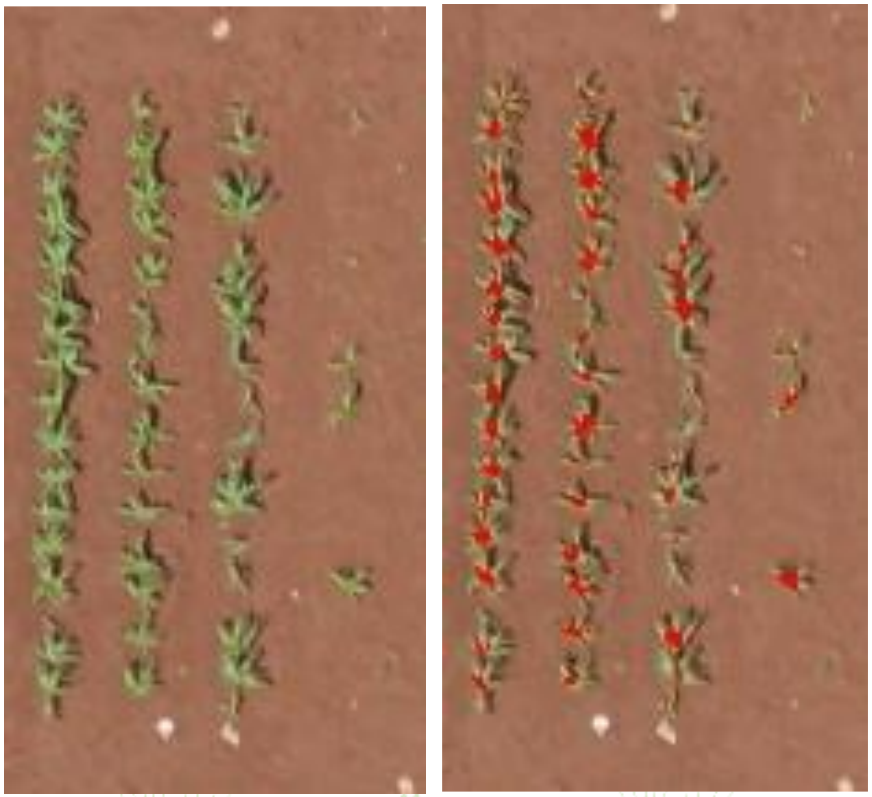
Plant height measurement using data transfer-enabled laser distance meter

CIMMYT

Phenotyping technologies

Platforms and tools

Plant Count



Plant count

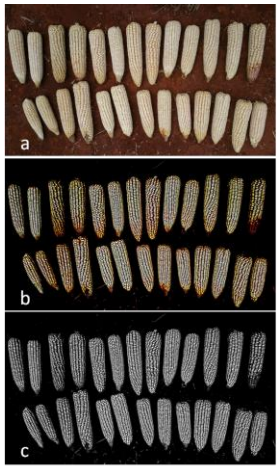
Tassel count

CIMMYT

Phenotyping technologies

Platforms and tools

Yield Components



Plot	Total Area	Mean Area	Mean Perim	Kernel Width	Kernel Length	Kernel Number	Total Grain Weight	KUI	N Cobs	Cob length	Cob width	CUI
1	251.10	0.22	2.66	0.4	0.8	2537	1080.89	0.0504	5	20.13	6.29	13.31
2	290.39	0.27	2.93	0.44	0.89	2406	1025.97	0.0680	6	19.55	6.04	26.66
3	149.22	0.21	2.62	0.38	0.79	1609	685.41	0.0479	5	15.51	5.15	21.49
4	185.55	0.25	2.71	0.41	0.85	1684	717.98	0.064	5	17.12	6.27	3.28
5	255.99	0.24	2.8	0.42	0.85	2354	1003.17	0.0562	6	17.70	6.03	23.05
6	308.11	0.23	2.74	0.41	0.81	2963	1262.57	0.0511	5	22.81	6.49	1.25

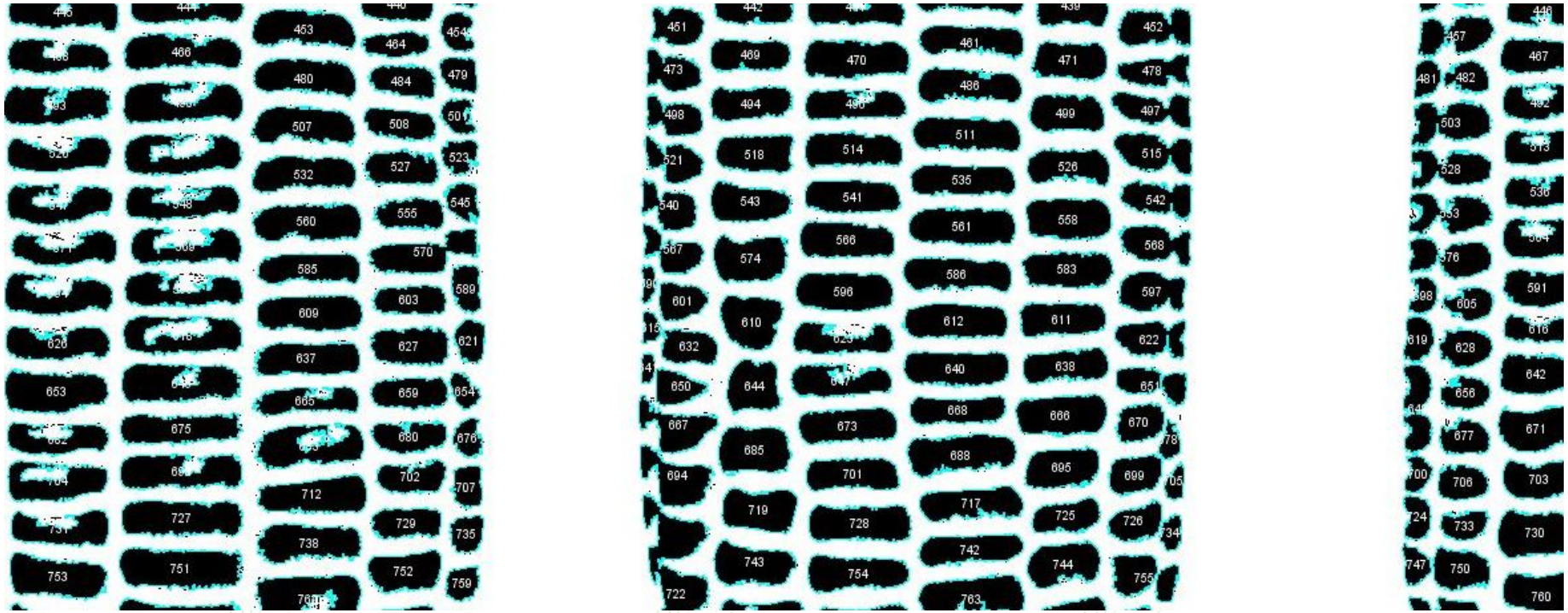
- Average cob size
- Cob number
- Cob uniformity index
- Total Kernel number
- Total Kernel weight
- Kernel row number
- Average kernel size
- Kernel uniformity index

CIMMYT

Phenotyping technologies

Platforms and tools

Yield Components



Phenotyping technologies

Platforms and tools

Yield Components

1

2

3

4

5

6

Phenotyping technologies

Platforms and tools

Yield Components

	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

Makanza et al. Plant Methods

CIMMYT

Phenotyping technologies

Platforms and tools

Value of Sensing Technology

Reduces time required for measurements by 50 to 90%

High Throughput

Reduces cost related to data collection by 25 to 75%

Cost Effective

Enables short revisit periods

Time Series Data

CIMMYT

Phenotyping technologies

Platforms and tools

UAV regulations challenges/options

Proximal Sensing Cart

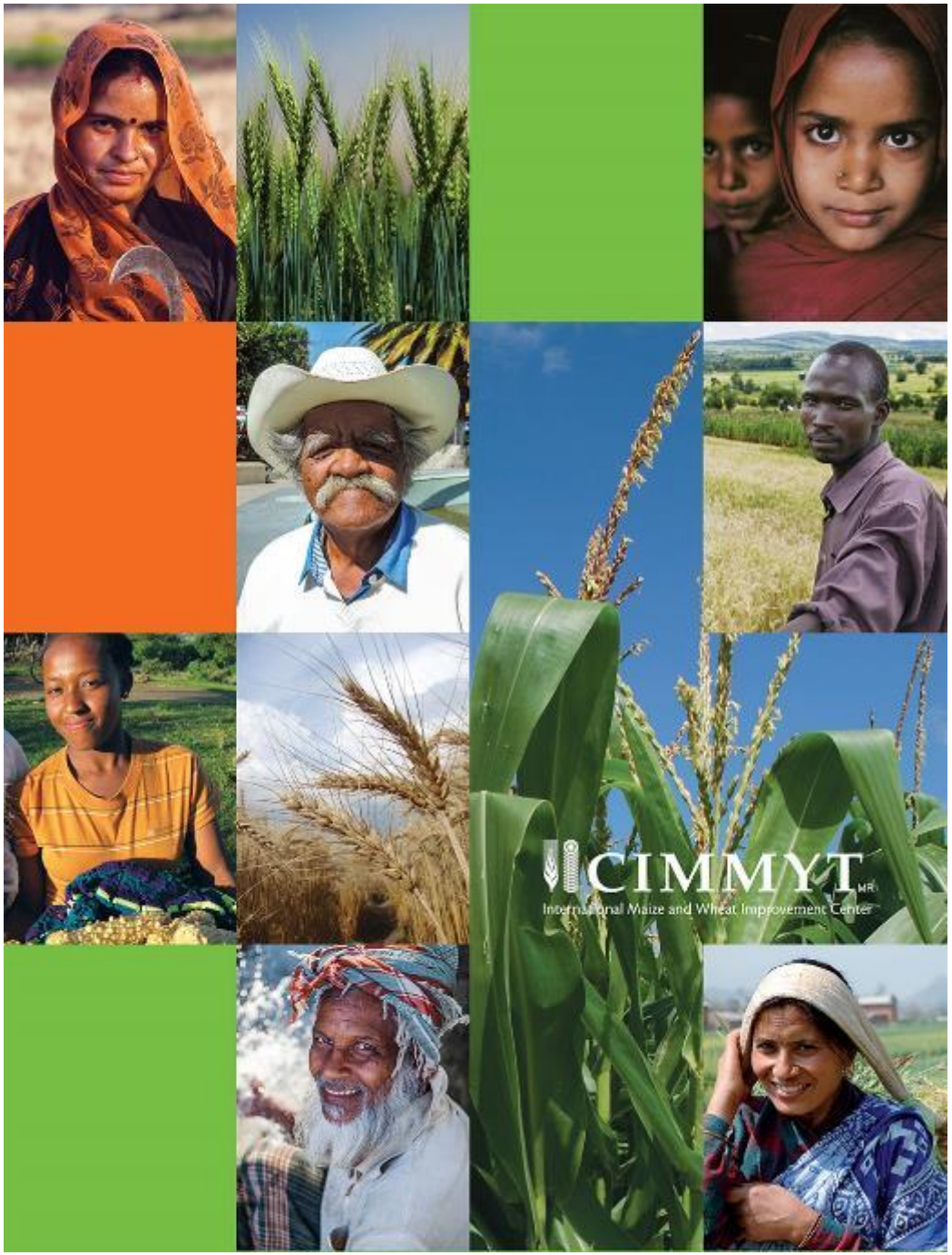
We Robotics

Robotics for the Benefit of All

Flying Labs

Service provision by private companies

CIMMYT



Thank you for your interest!