Science of Discovery through to Science of Delivery – How we achieve the SDGs together

47th Annual Group of AICRP on Sorghum

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

CGIAR RESEARCH PROGRAM ON Dryland Cereals
CGIAR RESEARCH PROGRAM ON Grain Legumes
LED BY ICRISAT
IN PARTNERSHIP WITH CIAT, ICARDA, IITA
and public and private institutes and organizations, governments, and farmers worldwide

SDGs

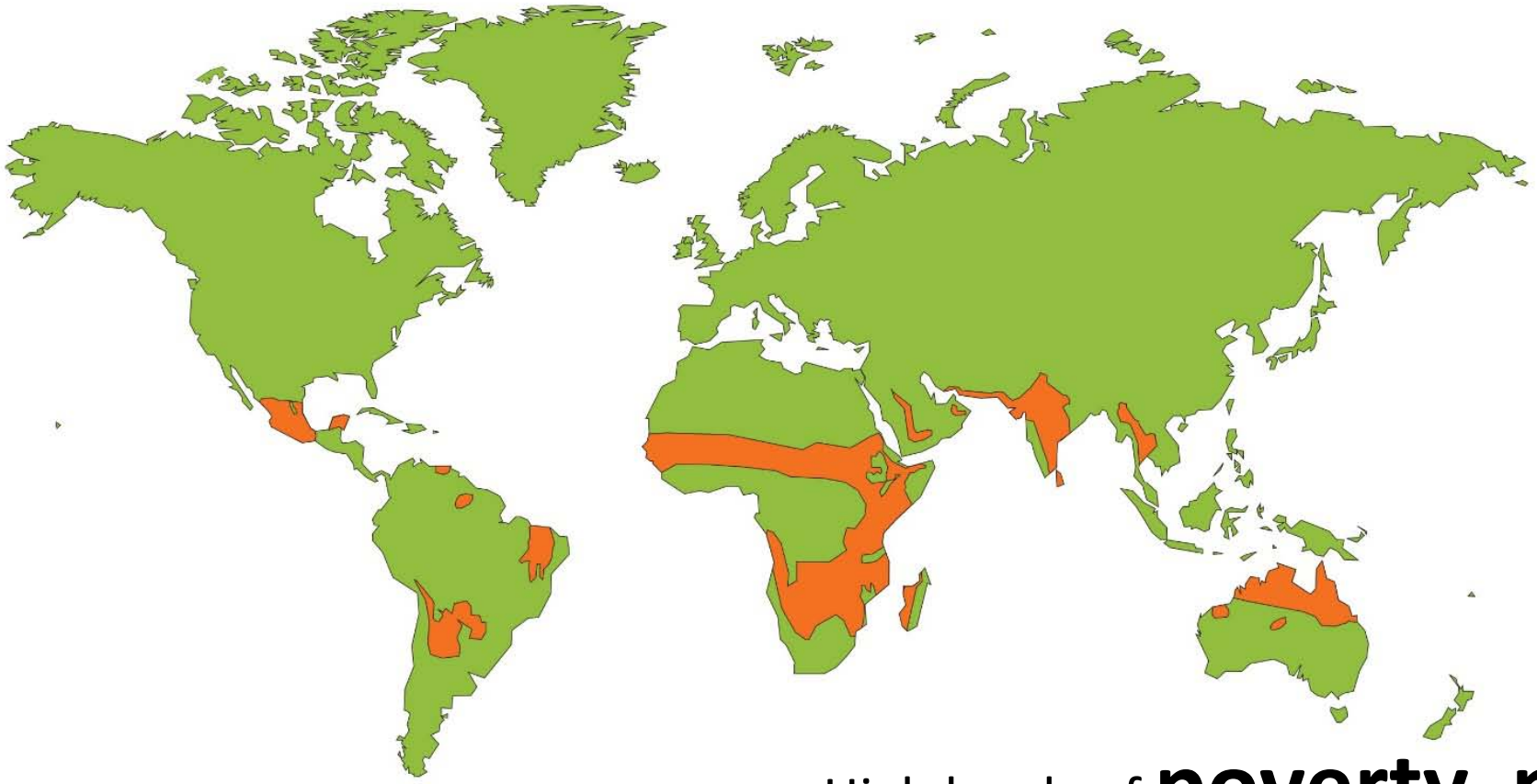
17 Sustainable Development Goals with emphasis on sustainable and equitable food systems

Climate Change

Climate change 'already affecting food supply' - UN

Report by climate change panel says global warming is fuelling not only natural disasters, but potentially famine - and war

Semi-Arid Tropics



Covers **6.5 million** sq. km.

Across **55** countries

with **2 billion** people

of which **644 million**

are the poorest of the poor

High levels of **poverty, malnutrition and environmental degradation**

Specialization in crops suitable for the **drylands**

Sorghum

Pearl millet
& Finger millet

Groundnut

Chickpea

Pigeonpea

smart food

Good for you
Good for the planet
Good for smallholder farmers

Our capabilities

Multidisciplinary high-class science

On the ground in Asia and Africa

Strong networks

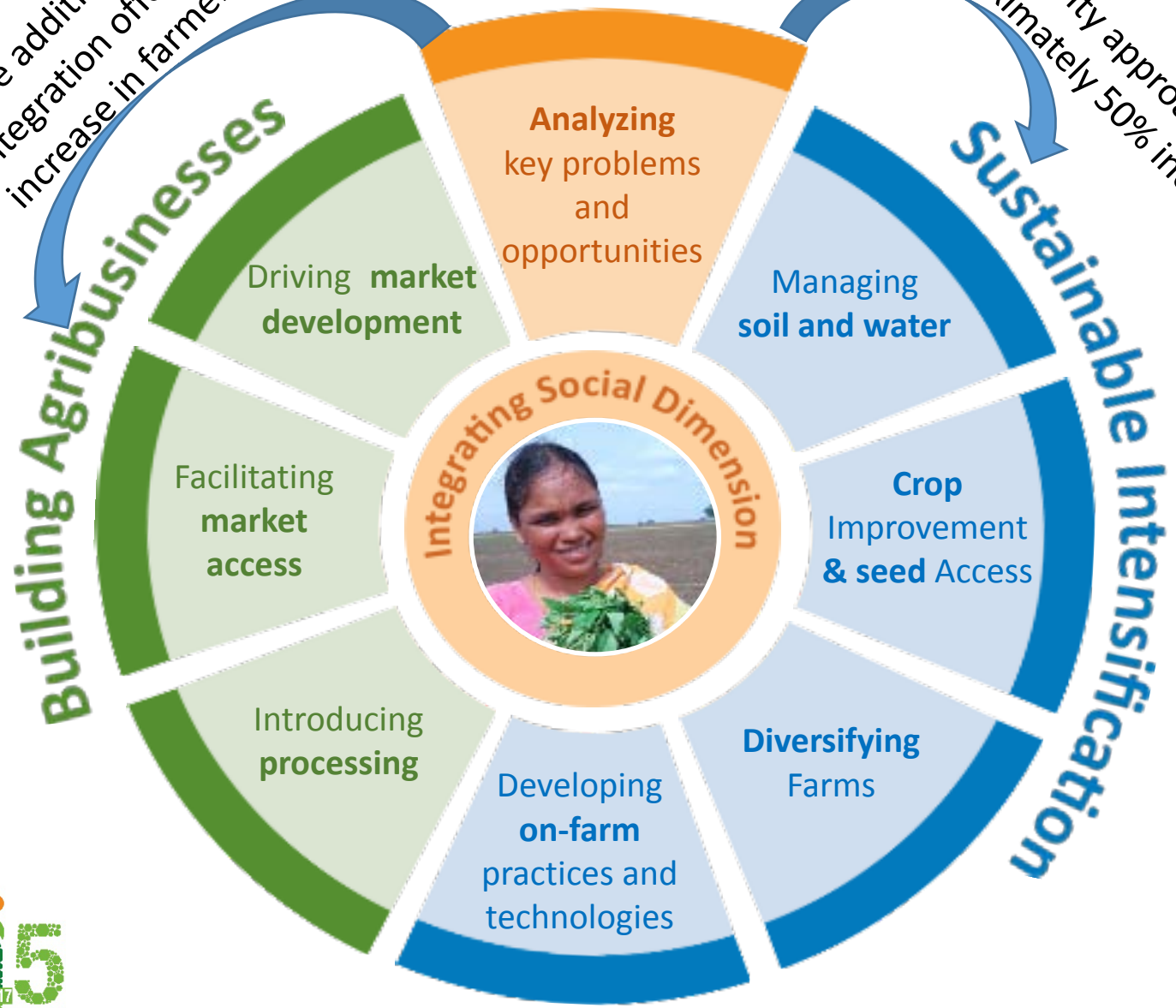
Participatory methods

Recognized as independent

Market-driven Innovation

Value addition & Market integration offers >100% increase in farmer incomes

Productivity approach offers approximately 50% increase



Cross-cutting issues

- **Mainstreaming nutrition**
- **Empowering women** – women are consulted, involved and supported to lead
- **Attracting youth** to agriculture

Approach for Adoption

- **Participatory approach and partnering** – working side by side
- **Building capacity** – at a national and local level
- **Integrating communications** - to build awareness and share knowledge
- **Monitoring and evaluation** – for feedback and adjustment
- **Policy support** – work closely with government to encourage the needed policies

Smart Foods – Millets and Grain Legumes

Good for You

Millets are:

- High in antioxidants
- High in proteins, vitamins and micronutrients
- *Finger millet has 3 times more calcium than milk*
- Low GI
- Gluten free
- Fights cancer, diabetes and heart disease

Good for the Planet

Millets are climate-smart crops that:

Can survive drought and high temperatures

Need less water than other cereals

New solutions needed to feed 9 billion by 2050.

Multiple uses exist with untapped markets, e.g.

Fodder

Biofuels

Good for smallholder farmers

Millets are the traditional crop for 2.5 billion people living in the drylands.

Millets are easier to grow for resource-poor farmers

Millets introduce on-farm diversity that improves farmers' resilience to climate change

smart food

Smart Foods: Nutri-Cereals

WHY DRYLAND CEREALS ?

- CLIMATE HARDY
- MICRONUTRIENT RICH
- CATERS TO 650+m PEOPLE

DEMAND

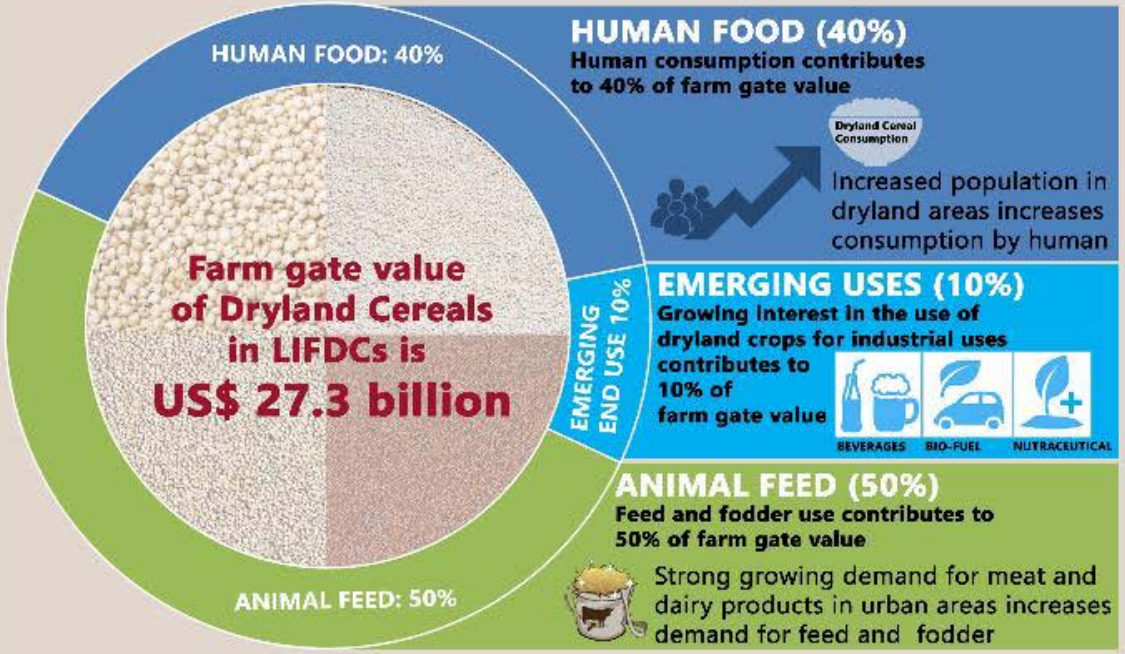
40%

YEAR 2020

By 2020 demand for dryland cereals in target regions will increase by about 40%

- IFPRI IMPACT MODEL

USAGE



TARGET CROPS AND COUNTRIES

BARLEY	FINGER MILLET	PEARL MILLET	SORGHUM
			
Ethiopia | India | Iran Kazakhstan | Morocco | Turkey	Ethiopia | Tanzania Uganda	Burkina Faso | India | Mali Niger | Nigeria | Senegal Sudan | Tanzania	Burkina Faso | Ethiopia | India | Mali | Mozambique Nigeria | Sudan | Tanzania

Science of Discovery through to **Science of Delivery**

- An interconnected world is enjoying an unprecedented pace of scientific discovery; however, we often underestimate the **Science of Delivery and Adoption of science-based solutions**

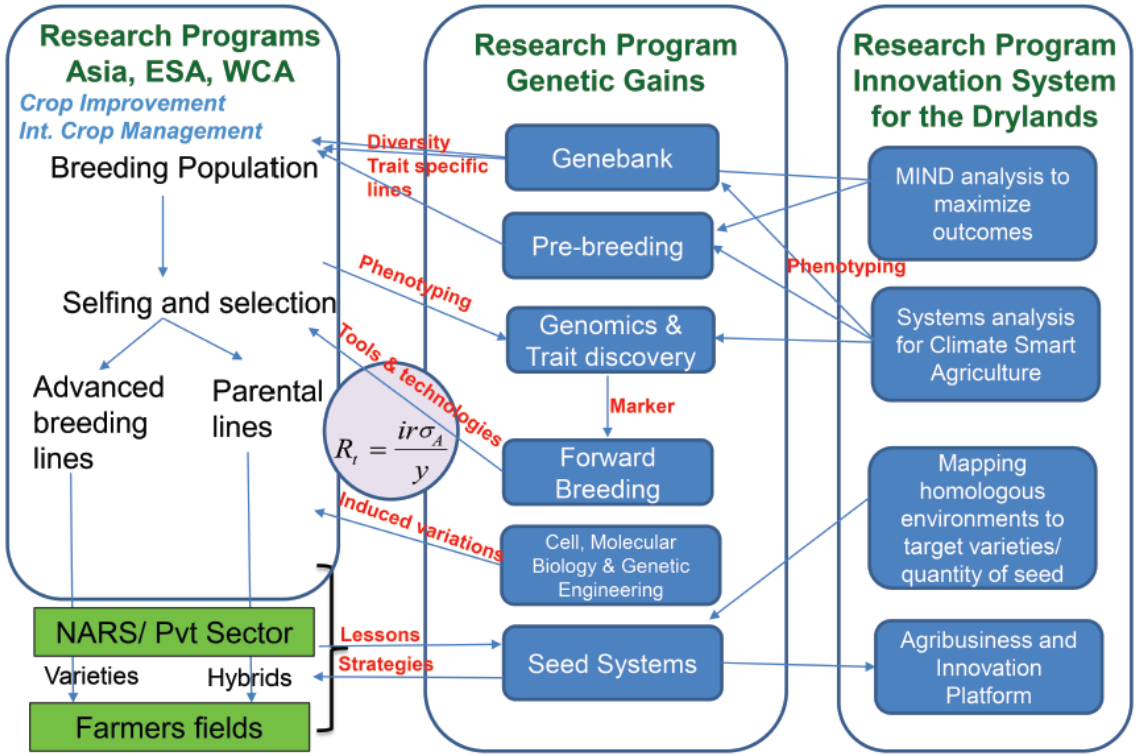
- ICRISAT works with national partners along national value chains in service of realizing national goals through:
  - Demand-driven innovation with rapid feedback loops
  - Anthropology of Adoption
  - Non-linear scaling through a consortium
  - Building and mentoring local capacity and advocates
  - Soft skills of science for brokering innovative partnerships
  - Pragmatic Policies for Prosperity to realize sustainable and equitable growth

Modernization of crop improvement

Sequencing and informatics Services

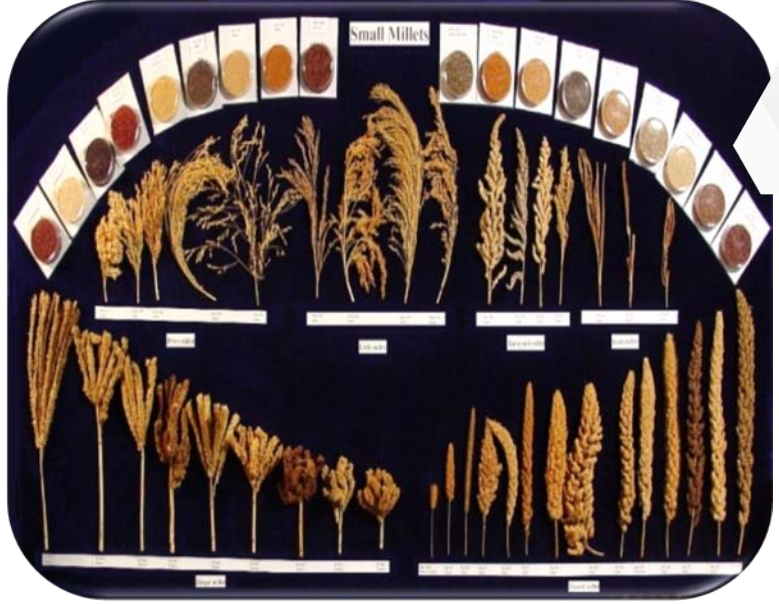
Genebank	Conserves, characterizes and distributes germplasm and identifies trait specific lines
Pre Breeding	Characterization of germplasm collection in support of breeding programs
Genomics & Trait Discovery	Development of genomic resources for allele discovery, and identification of markers/ genes for traits of interest
Forward Breeding	Provision of tools and technologies for molecular breeding
Cell, Mol Biol & Gen Engineering	Cell molecular biology research for generating targeted solutions
ESA-Biotechnology	Application of genomic tools for crop improvement in ESA
Seed System	Knowledge platform for innovative seed systems that accelerate the delivery and replacement rate for improved varieties

Integrated Breeding Program

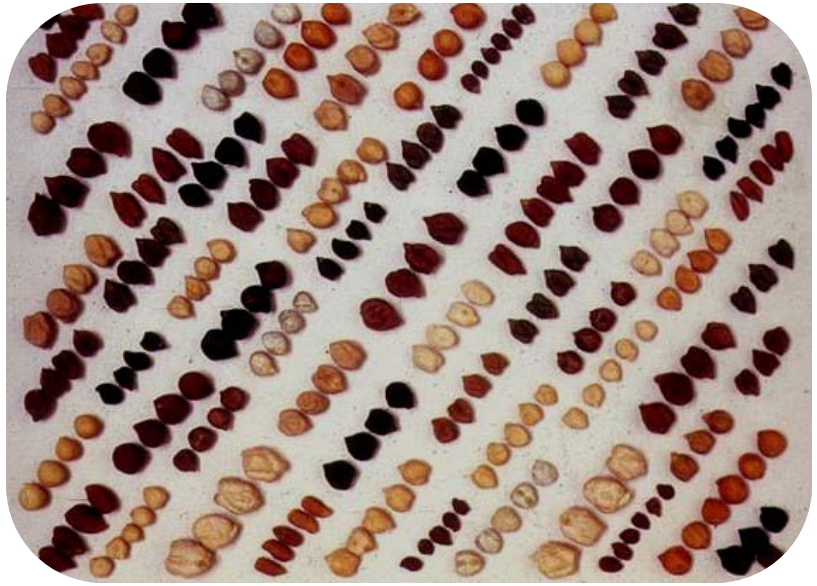


Sorghum

Pearl millet



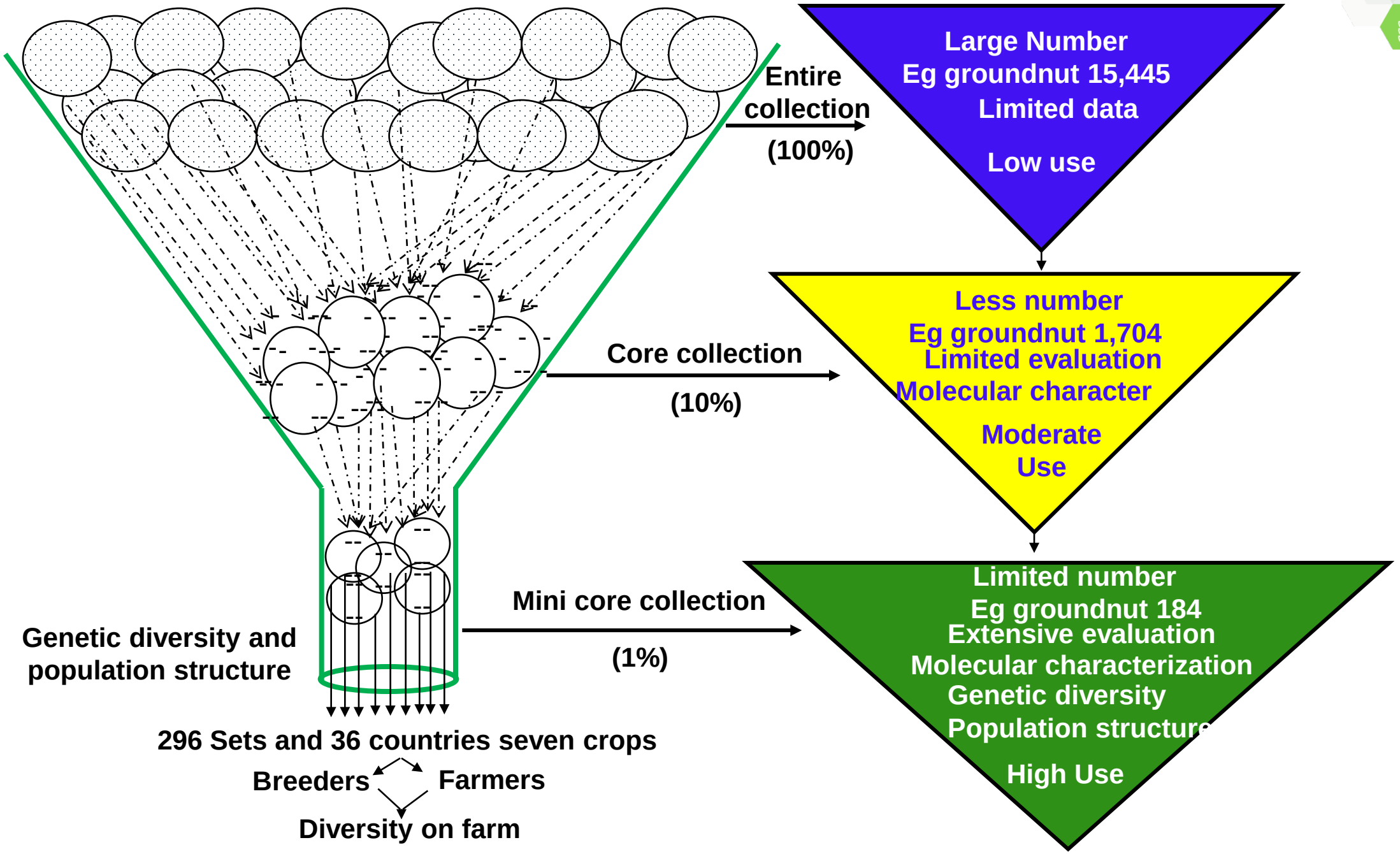
Small millets



Chickpea

Pigeonpea

Groundnut


Entire collection
(100%)
Large Number
Eg groundnut 15,445
Limited data
Low use
Core collection
(10%)
Less number
Eg groundnut 1,704
Limited evaluation
Molecular character
Moderate Use
Mini core collection
(1%)
Limited number
Eg groundnut 184
Extensive evaluation
Molecular characterization
Genetic diversity
Population structure
High Use
Genetic diversity and population structure
296 Sets and 36 countries seven crops
Breeders
Farmers
Diversity on farm

Mini-core collections of germplasm at ICRISAT

Crop	Entire collection	Mini core number	% of entire	Traits used	Reference
Chickpea	16,991	211	1.24	16	Upadhyaya and Ortiz 2001; TAG 102:1292-1298
Groundnut	14,310	184	1.28	34	Upadhyaya et al. 2002; Crop Sci. 42: 2150-2156
Pigeonpea	12,153	146	1.20	16	Upadhyaya et al. 2006; Crop Sci. 46:2127-2132
Sorghum	22,473	242	1.08	21	Upadhyaya et al. 2009; Crop Sci. 49:1769-1780
Pearl millet	20,844	238	1.14	12	Upadhyaya et al. 2011: Crop Sci. 51 :217-223
Finger millet	5,940	80	1.34	18	Upadhyaya et al. 2010: Crop Sci. 50: 1924-1931
Foxtail millet	1,474	35	2.37	21	Upadhyaya et al. 2011; Field Crops Research 124:459-467

Utilization of germplasm collections

$< 1\ \%$

Finger and Foxtail Millet Demonstration trials

Africa: 70 trials

Finger millet: 22 in Kenya, 16 in Tanzania and 32 in Uganda

India: 192 trials

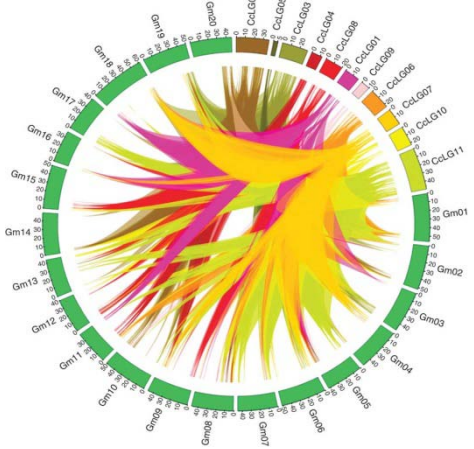
Finger millet: 24 in Mandya, 23 in Nandyal, 22 in Vizianagaram and 32 in Dholi

Foxtail millet: **1**4 in Mandya, 23 in Nandyal, 22 in Vizianagaram and 32 in Dholi

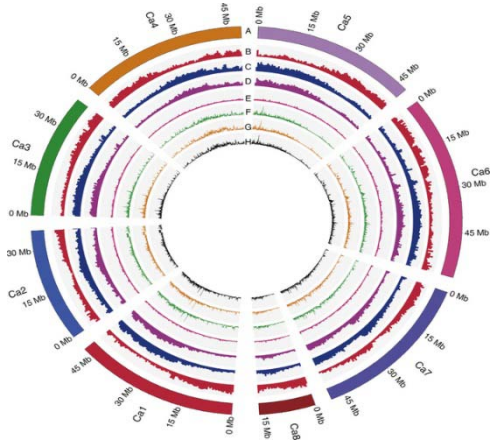
Farmers evaluate accessions at the on-farm trial field day at Alupe, Kenya

Science of Discovery: Genomics

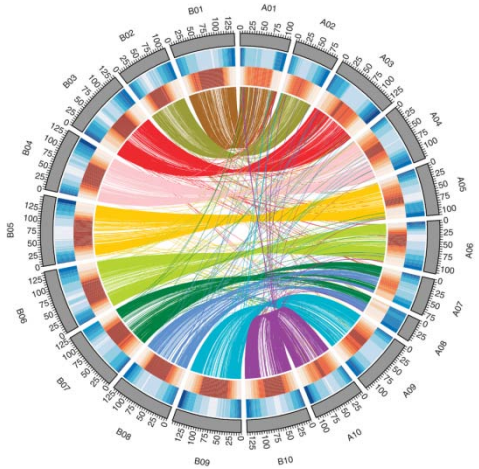
Majority of genomes sequenced using Illumina seq technology



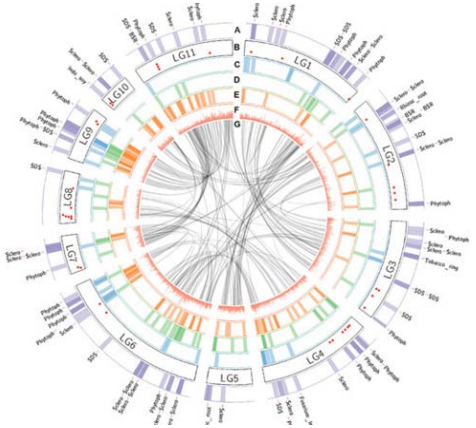
Pigeonpea
(*Nature Biotechnology- 2012*)



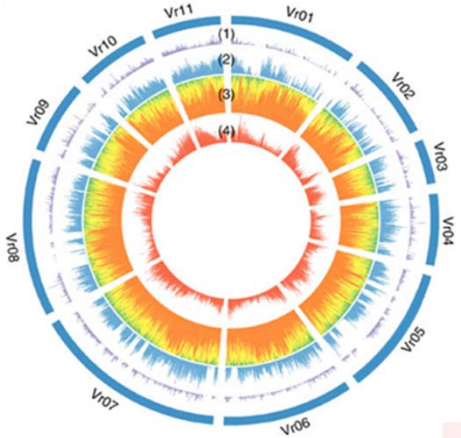
Chickpea
(*Nature Biotechnology- 2013*)



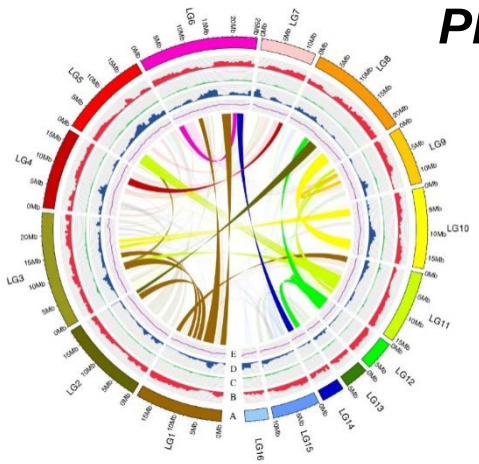
Groundnut
**(*Nature Genetics- 2016*
PNAS 2016)**



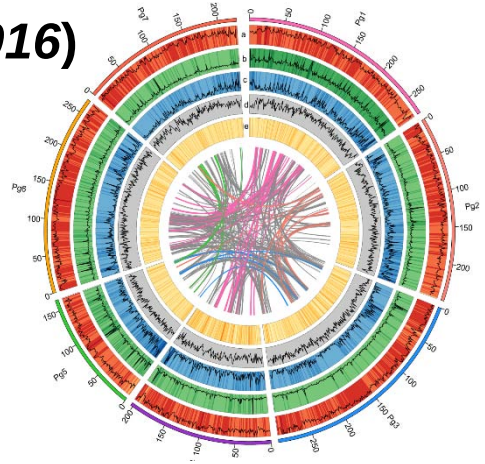
Adzuki bean
**(*PNAS 2015*
Sci Rep 2015)**



Mungbean
(*Nature Commun 2014*)



Sesame
(*Genome Biology- 2014*)

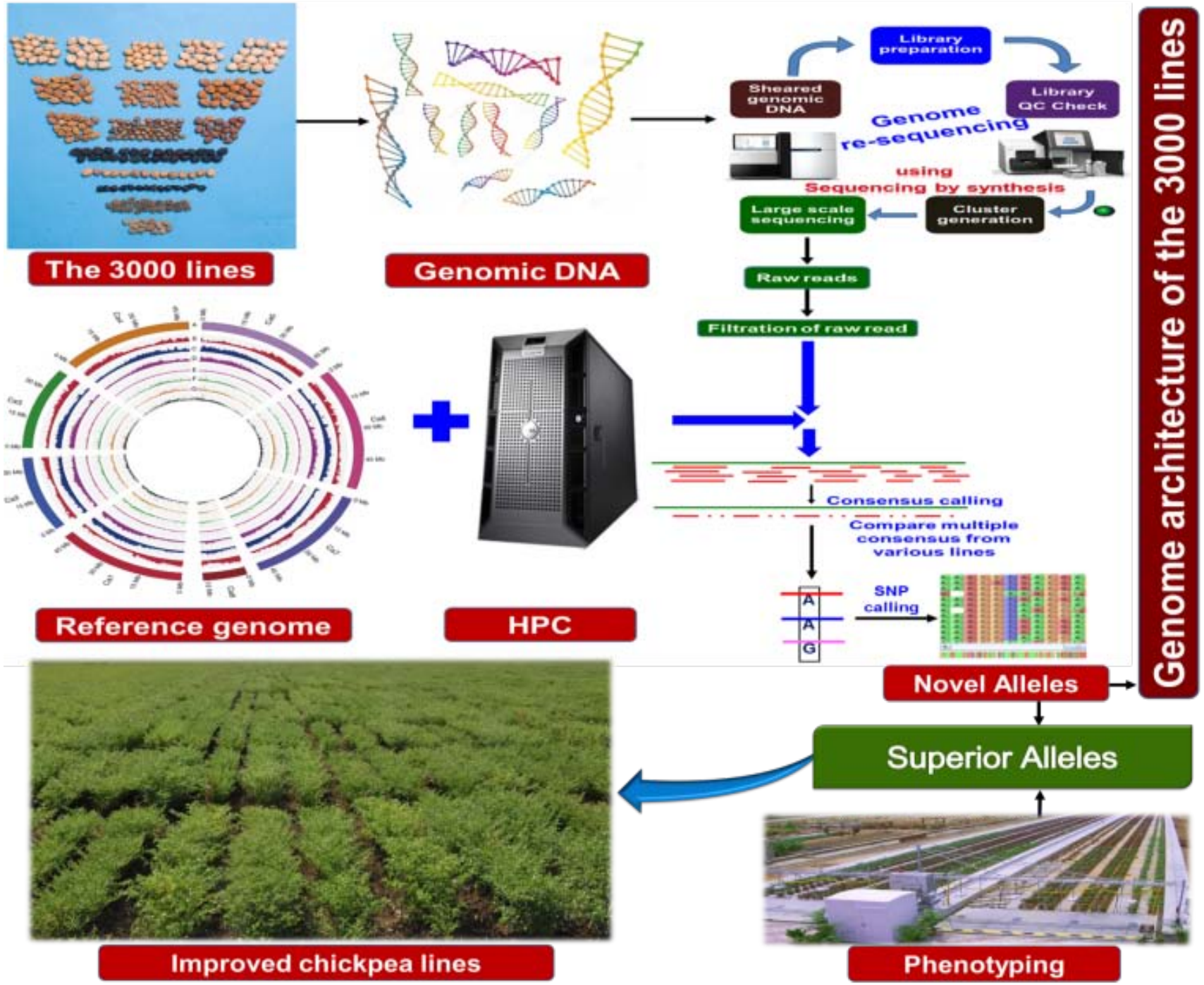


Pearl millet- 2017
(*in revision*)

DivSeek

The 3000 Chickpea Genome Sequencing Initiative

Sequencing data already generated



Partner

1972-2017 ICRISAT

ICARDA

Can we sequence entire germplasm collection?

ICRISAT holds over 124,000 germplasm accessions from 144 countries!

Chickpea (20.5K)

Pigeonpea (14K)

Groundnut (15.5K)

Sorghum (38K)

Pearl millet (23K)

Finger/ small millets (11K)

nature International weekly journal of science

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NATURE | COMMENT

Agriculture: Feeding the future

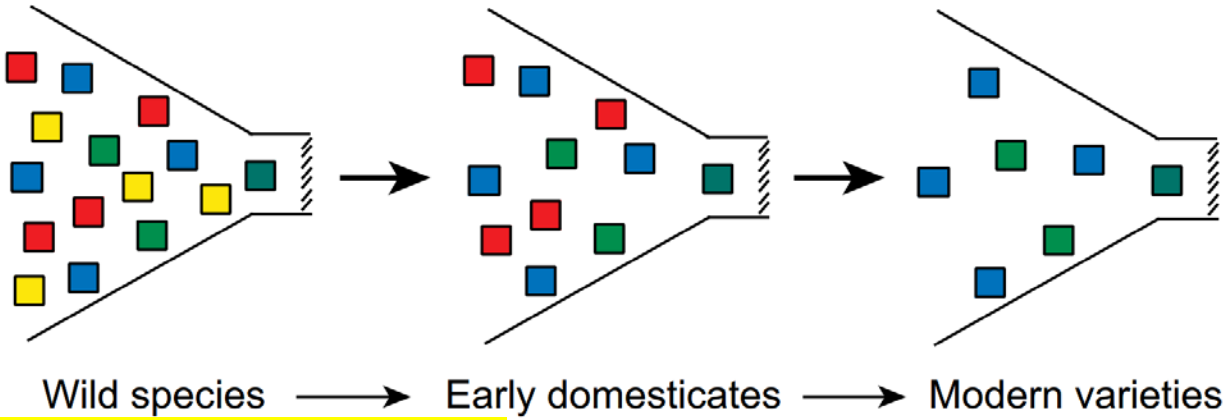
Susan McCouch, Gregory J. Baute, James Bradeen, Paula Bramel, Peter K. Bretting, Edward Buckler, John M. Burke, David Charest, Sylvie Cloutier, Glenn Cole, Hannes Dempewolf, Michael Dingkuhn, Catherine Feuillet, Paul Gepts, Dario Grattapaglia, Luigi Guarino, Scott Jackson, Sandra Knapp, Peter Langridge, Amy Lawton-Rauh, Qui Lijua, Charlotte Lusty, Todd Michael, Sean Myles, Ken Naito, Randall L. Nelson, Reno Pontarollo, Christopher M. Richards, Loren Rieseberg, Jeffrey Ross-Ibarra, Steve Rounsley, Ruaraidh Sackville Hamilton, Ulrich Schurr, Nils Stein, Norihiko Tomooka, Esther van der Knaap, David van Tassel, Jane Toll, Jose Valls, Rajeev K. Varshney, Judson Ward, Robbie Waugh, Peter Wenzl & Daniel Zamir – Show fewer authors

Affiliations | Corresponding author

Nature **499**, 23–24 (04 July 2013) | doi:10.1038/499023a

Published online 03 July 2013

Identify new alleles for crop improvement



Tanksley and McCouch 1997

- **Harness the wealth of genetic variations provided by nature and warehoused in seed repositories**
- **Tremendous genetic potential locked up in seed banks**
- **Tools of genome research may unleash the genetic potential of our wild and cultivated germplasm resources**

~122,000 accessions (ICRISAT gene bank)

Re-sequence the entire germplasm @ 100$ per sample

Cost 12 M$

Solution??

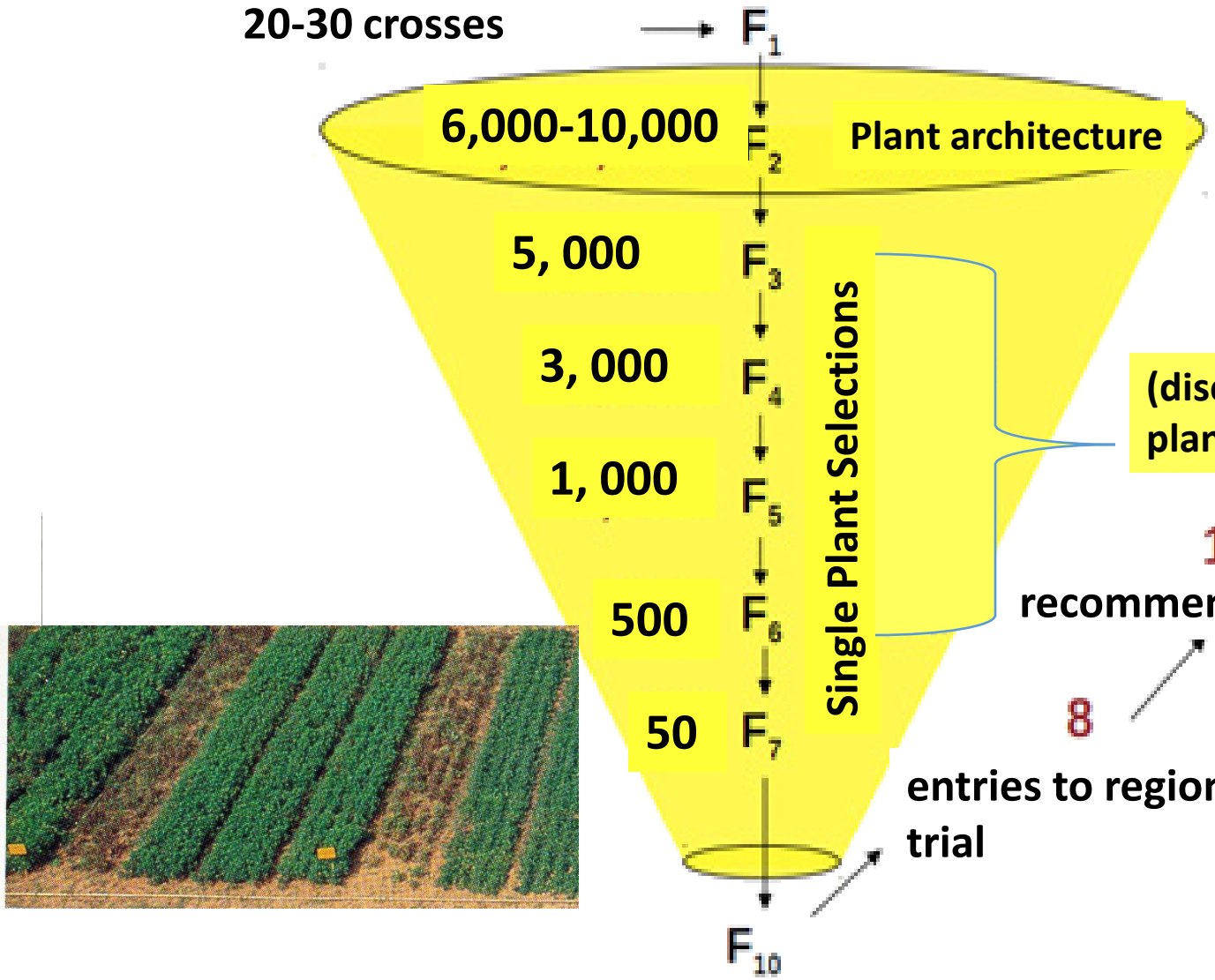
Reduce the cost to around 5-6 M$

Areas for collaboration?

Illumina places HiSeq X Ten System at ICRISAT

ICRISAT secures resources from CSR to cover consumable costs

Time to optimize classical breeding funnel



(disease, days to flowering, plant stand etc

1

recommended variety

8

entries to regional trial

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

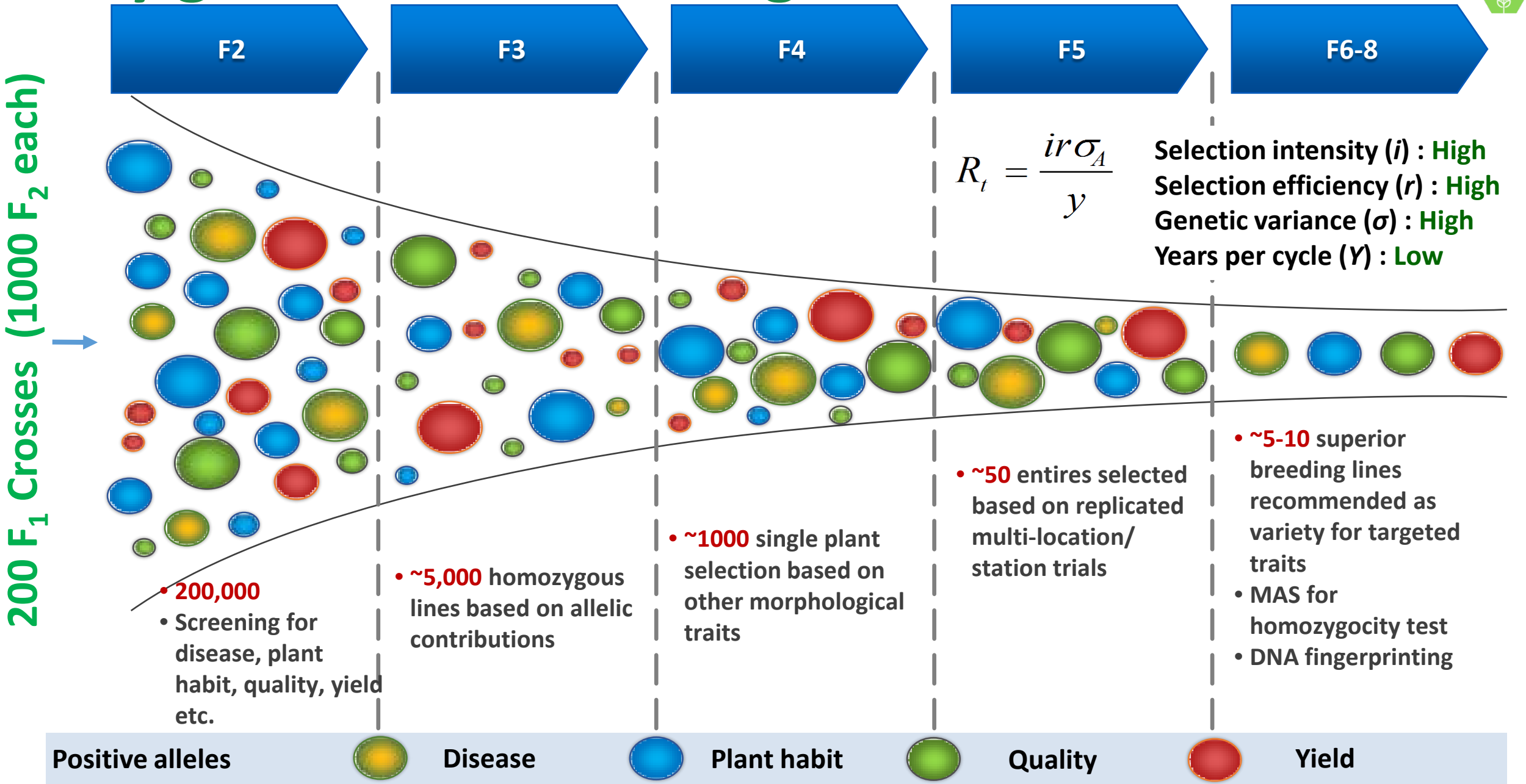
Selection intensity (*i*) : Low

Selection efficiency (*r*) : Low

Genetic variance (*σ*) : Low

Years per cycle (*Y*) : High

Early generation screening for *must-have* traits



HTPG project to enable plan working

High-throughput low-cost genotyping

- ICRISAT-led project in collaboration with CIMMYT, IRRI funded by BMGF

- Agreement between Intretek and ICRISAT on behalf of CGIAR centers
- CGIAR centers and NARS partners collect sample in an “automated" manner
- Samples can be submitted to Intertek – Hyderabad or Alnarp
- Cost- $1.5 per sample (includes DNA prep) for 10 SNPs
- Need to develop larger and more diverse populations

Leaf sampling devices:

PlantTrak Hx

AK-EP-100

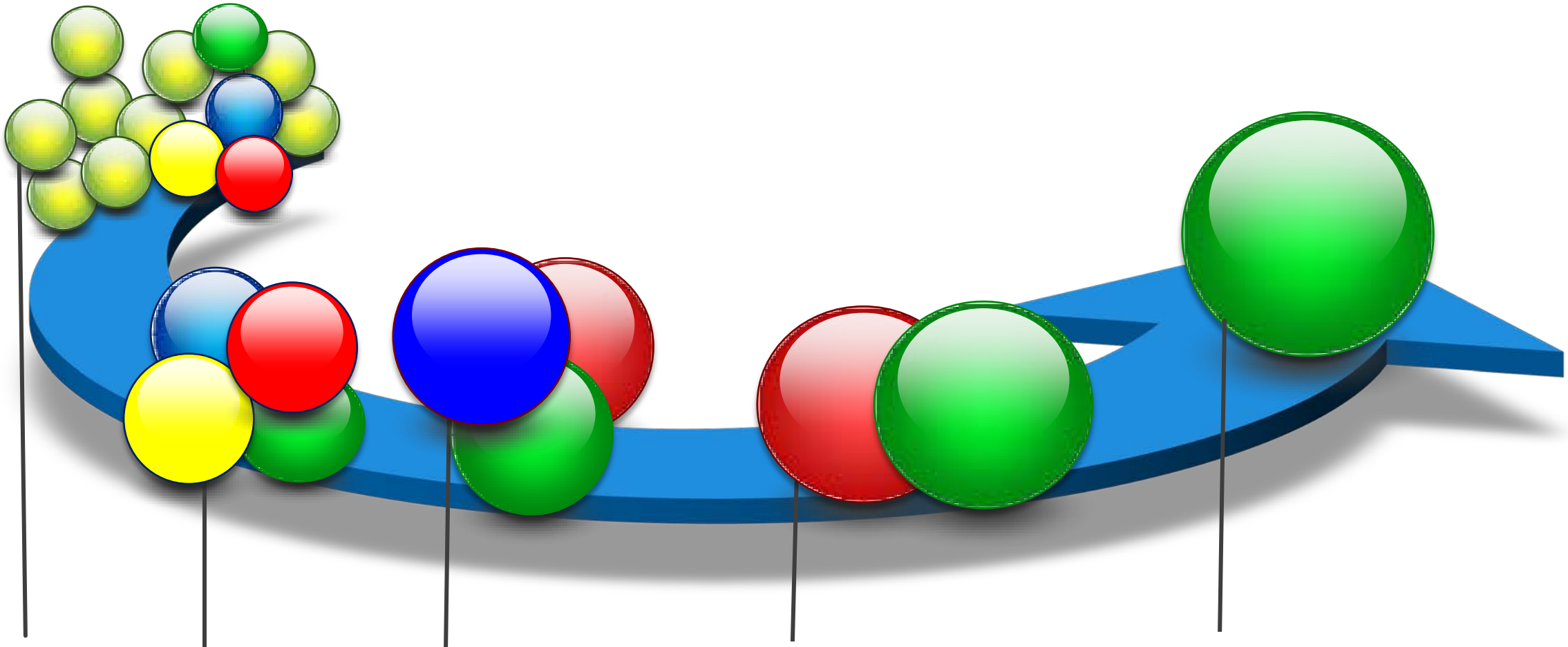
Target Samples/ year:

CIMMYT	300,000
ICRISAT	240,000
IRRI	150,000
IITA	50,000
CIAT	25,000
CIP	25,000
AfricaRice	25,000

Target crops

Maize
Rice
Wheat
Chickpea
Groundnut
Common bean
Cowpea
Cassava
Sweet potato
Potato

Develop more diagnostic markers!



Markers

Polymorphic markers

Markers on genetic map

Markers associated with major QTL/ gene

Marker impacting breeding selection

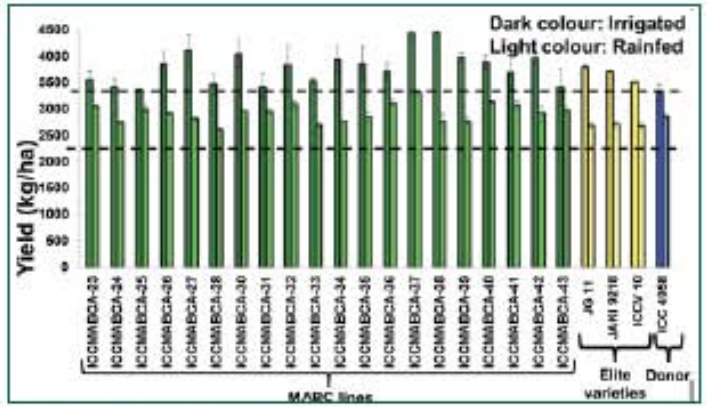
Selection of genotyping platform

Platforms	Current cost	Target cost
Whole genome re-sequencing (1 Gb; 5× – 10×)	$500 per sample	$50 - 100 per sample
Genotyping by sequencing (5000-1000 SNP markers)	$45 - 50 per sample	$20 per sample
SNP Arrays/chip (50,000 SNP markers)	$50 per sample	$15 - 20 per sample
KASP markers on HTPG (10 SNP markers)	$1.5 per sample including DNA isolation	$1 per sample including DNA isolation
New genotyping method (100-500 SNP markers)*	*NA*	*$5 per sample*

**Efforts have been initiated by Illumina*

Genome to fields - *FASTER*!

1. Improved lines with enhanced yield in chickpea



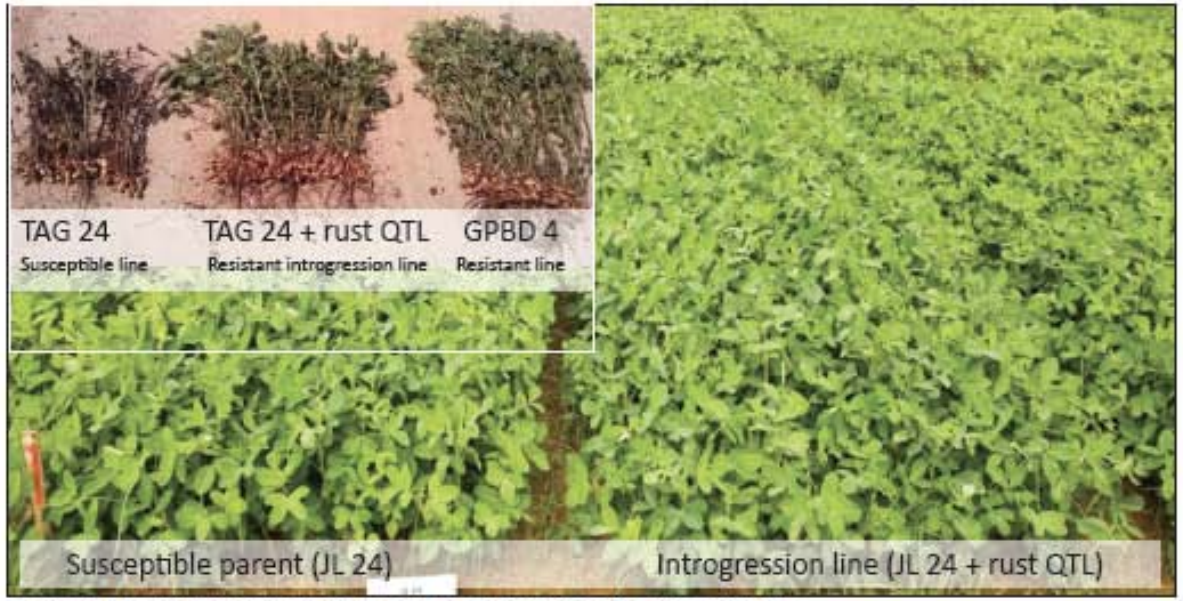
12% higher yield under rainfed and 24% higher yield under irrigated condition

2. Improved lines with disease resistance in chickpea

Ascochyta blight resistant line

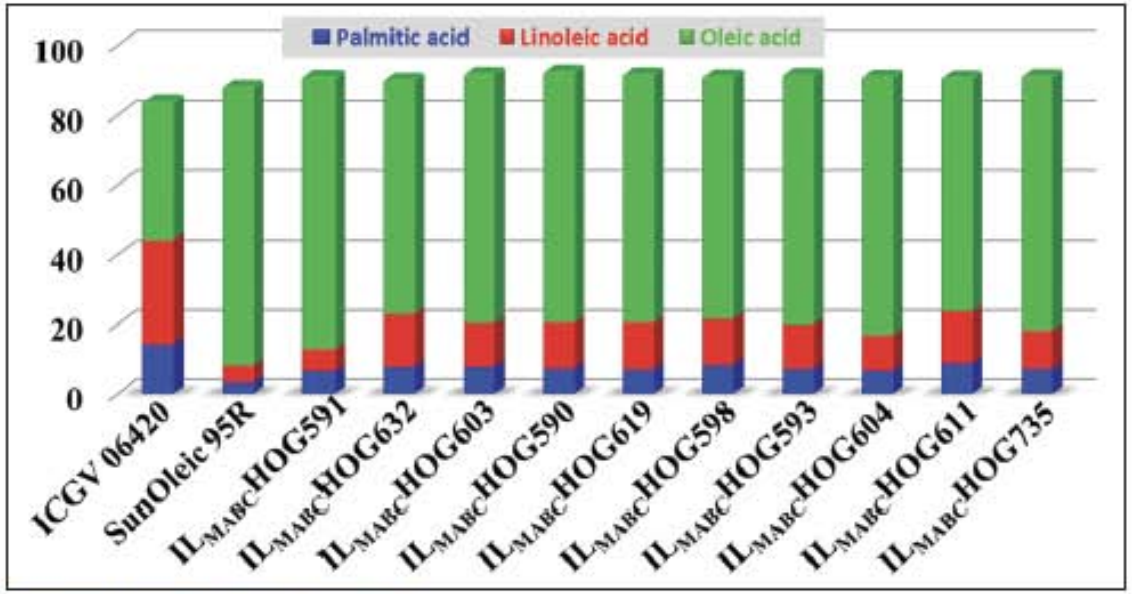
Fusarium wilt resistant line

3. Improved lines for foliar disease (rust and late leaf spot) resistance in groundnut



Improved lines showed 56-96% higher pod yield and early maturity

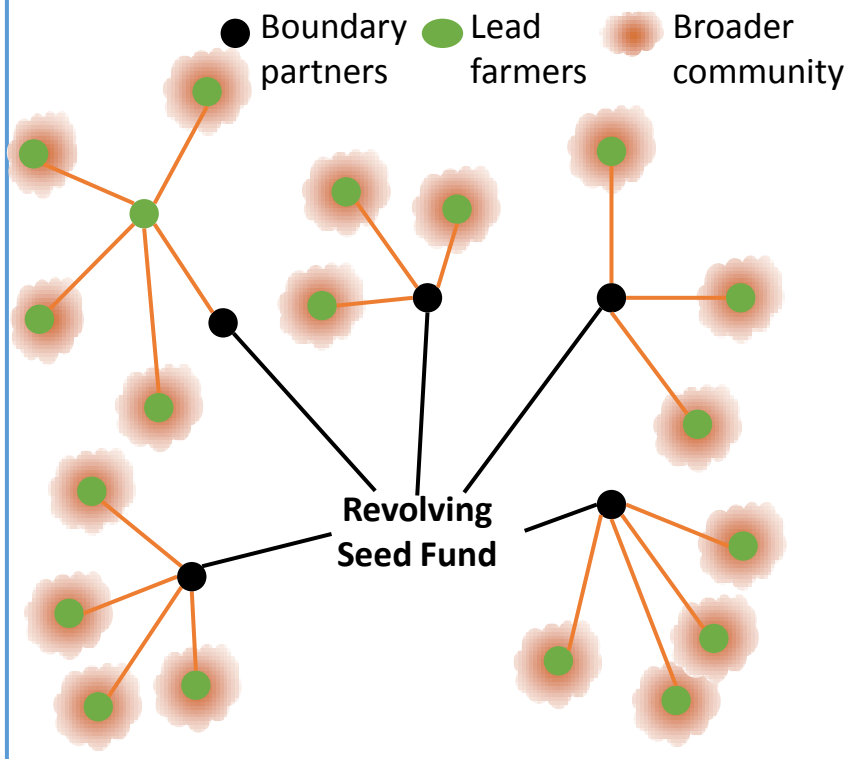
4. Improved lines for high oleic acid in groundnut



Improved lines upto 80% oleic acid

Science of Delivery: Seed Systems

ICRISAT has built a large network of delivery partners capable of identifying and equipping lead farmers …



Boundary partners are community based NGOs & government extension system with aligned goals

Lead farmers have interest and capacity to assist others in community, are influential and trusted, and can take risk with testing new technologies

… who rapidly mobilized others in their community to adopt new varieties, thereby motivating seed companies to produce, promote and distribute improved varieties

Participatory Variety Selection – asking the farm family what they want in a new variety

Five new varieties, including ICGV-SM 03517 now called Wamusanga, were released in September 2015

Holistic Scaling-up in Karnataka

Impacts

- 4.75 million farmers have benefited over 5 years
- 7.4 million ha: Rainfed area covered with improved management practices
- 3-14:1 benefit-cost ratio
- 20 – 66% increase in crop yield
- USD 353 million: Net benefit accrued in 5 years
- Rise in agriculture growth annually above 5% since 2009

Interventions

- Integrated soil-water-crop management practices
- Knowledge-based entry point for increasing the awareness about soil fertility status
- On-farm diversification
- Identifying and popularizing high-yielding, drought-resistant crop cultivars
- Capacity building on best management practices
- Empowered farmers as extension agents
- Innovative ICT-based extension system through public-private partnership
- Rural infrastructure for timely input delivery
- Promotion of mechanization
- Monitoring & Evaluation at regular intervals by high powered committee
- The Bhoochetana project is implemented with the local organizations and people having ownership of the process.

Digital Agriculture

- Spatial Data Infrastructure
- Cloud Computing
- Mobile
- IOTs
- Drones (UAVs) & Remote Sensing
- Image Processing
- Advanced Analytics & Artificial Intelligence
- Unique Identifiers
- MOOCs to personalize education

Home | Business Today | FEATURES | January 15, 2017 | Story

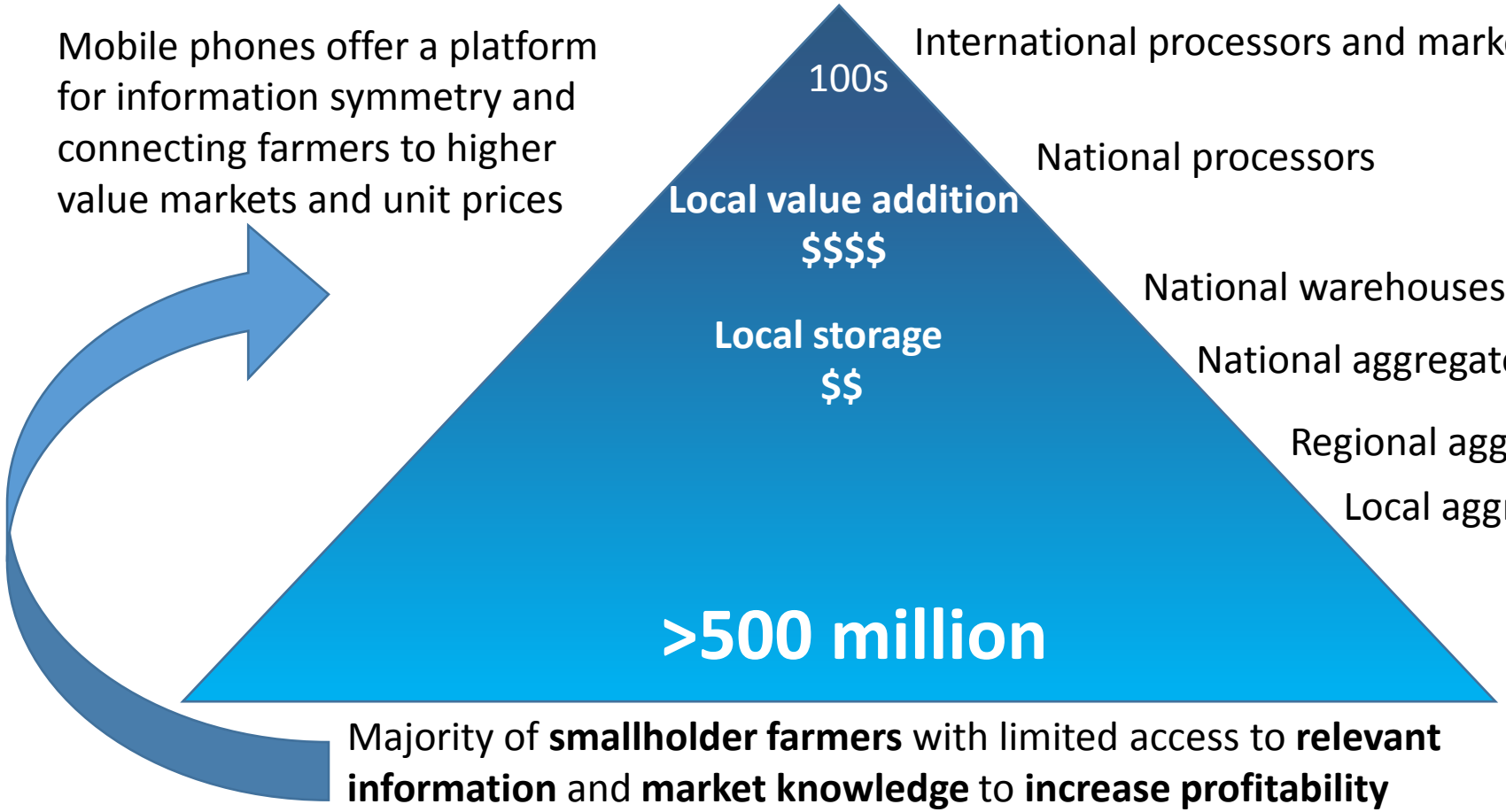
Digital agriculture empowers farmers

David Bergvinson Delhi Print Edition: January 15, 2017

http://www.businesstoday.in/magazine/features/digital-agriculture-empowers-farmers/story/242966.html

Pyramid of Economic Opportunity

Mobile phones offer a platform for information symmetry and connecting farmers to higher value markets and unit prices



International processors and markets

National processors

National warehouses

National aggregators

Regional aggregators

Local aggregators

Majority of **smallholder farmers** with limited access to **relevant information** and **market knowledge** to **increase profitability**

Value Chains and Country Strategies

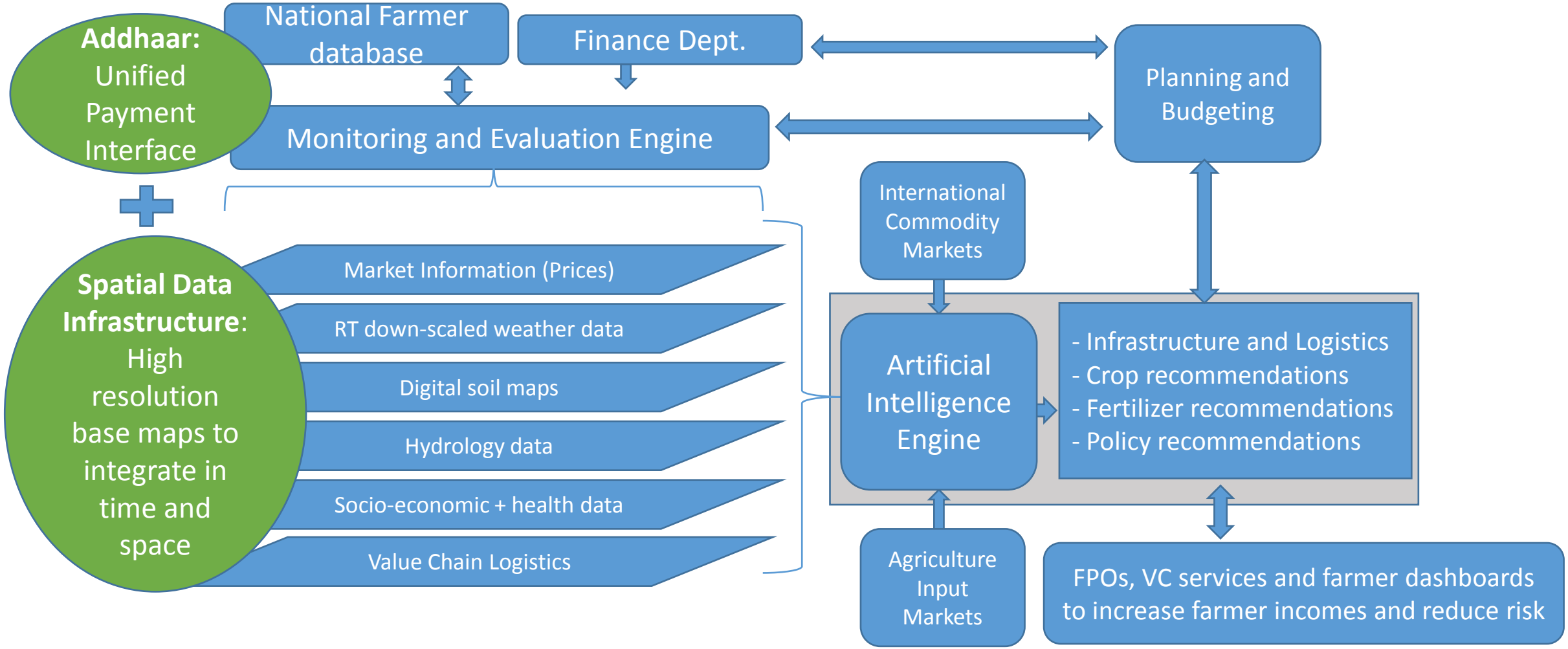
Demand-driven innovation

Backward integration of farmers to markets

Research and development			Inputs and farmer services				Post-harvest handling and access to markets		
Discovery	Crop improvement	Agronomic research	Seed systems	Other input systems	Farm management	Knowledge exchange	Aggregation, quality and storage	Processing	End-user demand

Value Chain Approach Guides State/Country Strategies

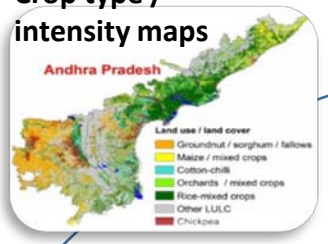
Smart Development Infrastructure to support **Convergence, Optimize Resources, Manage Risk and Increase Rural Incomes**



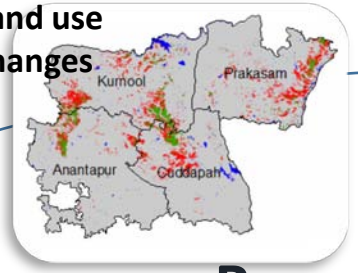
Geospatial/Temporal data feed into advanced analytics to guide farmers (profitability, minimize risk, improve availability of nutritious food) and support governments in planning and investments

Geospatial products for SAT

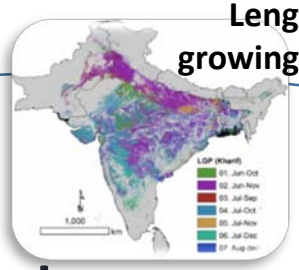
Crop type / intensity maps



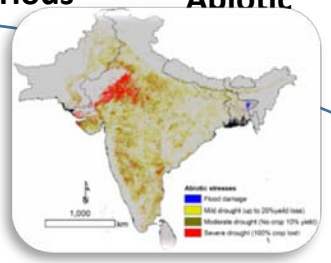
Land use changes



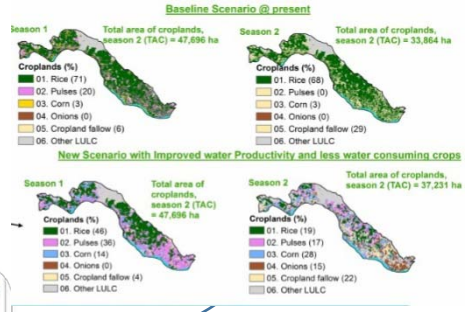
Length of growing periods



Abiotic



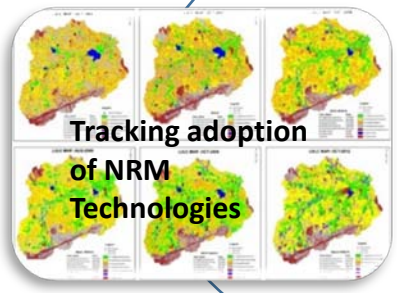
Water productivity



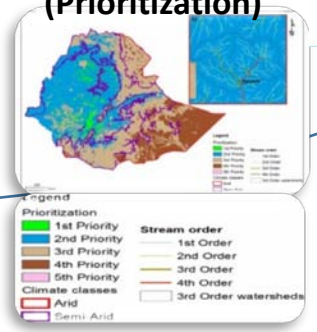
Research groups

- Breeders
- System modelers
- Social scientists
- Hydrologists
- Planning departments

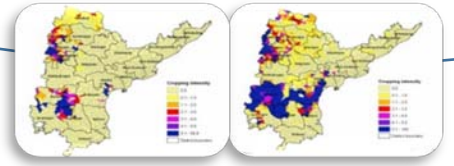
Tracking adoption of NRM Technologies

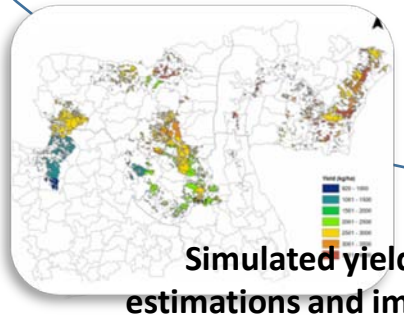


Spatial modeling (Prioritization)



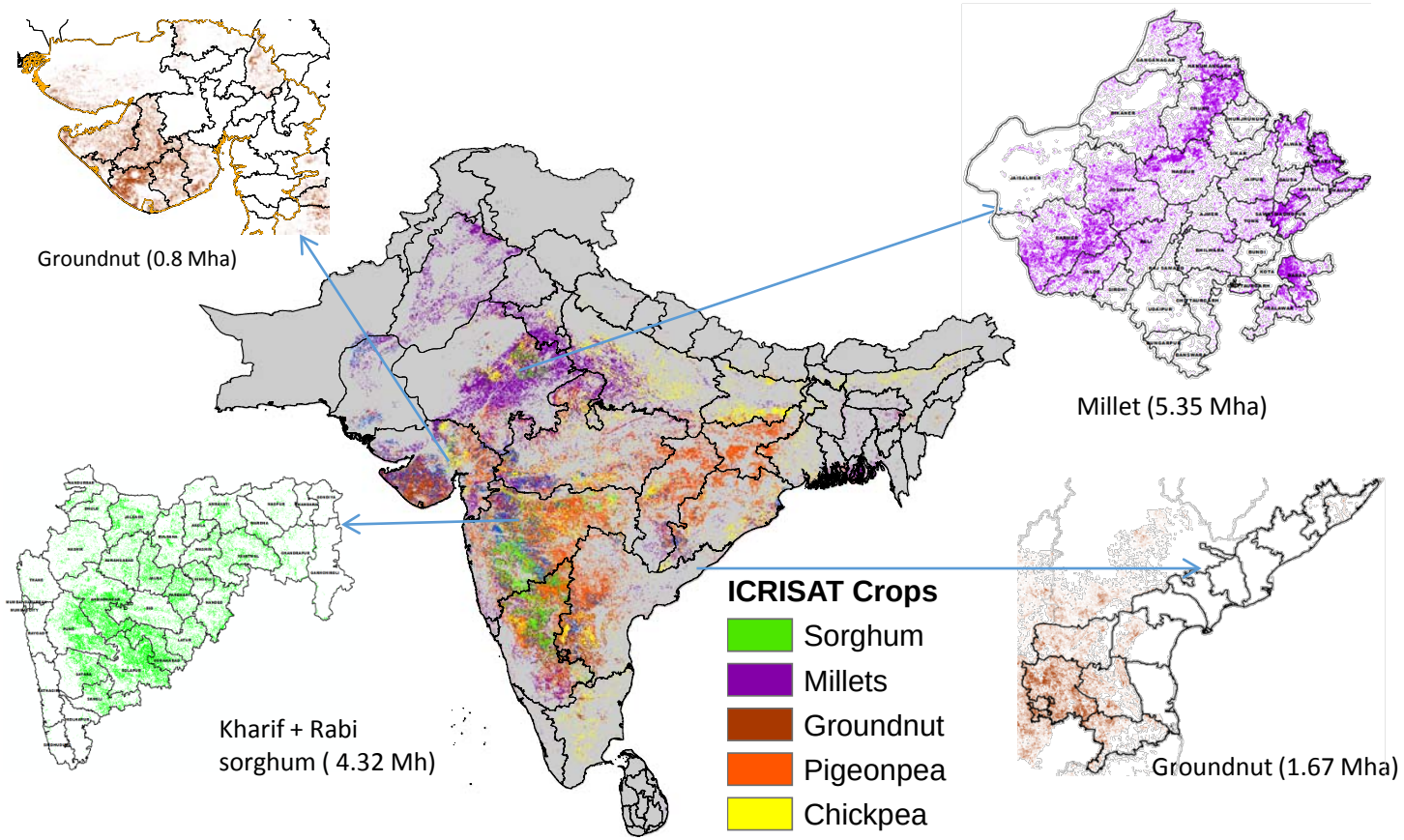
Impact assessment





Simulated yield estimations and impact

Cropland classes



Thank you

INTERNATIONAL CROPS RESEARCH
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Selected **Impacts** of **ICRISAT'S** work

Holistic Scaling-up in Karnataka

Impacts

- 4.75 million farmers have benefited over 5 years
- 7.4 million ha: Rainfed area covered with improved management practices
- 3-14:1 benefit-cost ratio
- 20 – 66% increase in crop yield
- USD 353 million: Net benefit accrued in 5 years
- Rise in agriculture growth annually above 5% since 2009

Interventions

- Integrated soil-water-crop management practices
- Knowledge-based entry point for increasing the awareness about soil fertility status
- On-farm diversification
- Identifying and popularizing high-yielding, drought-resistant crop cultivars
- Capacity building on best management practices
- Empowered farmers as extension agents
- Innovative ICT-based extension system through public-private partnership
- Rural infrastructure for timely input delivery
- Promotion of mechanization
- Monitoring & Evaluation at regular intervals by high powered committee
- The Bhoochetana project is implemented with the local organizations and people having ownership of the process.

Crop Improvement: Chickpea in Andhra Pradesh and Telangana

Impacts

- ICRISAT-India partnership varieties cover over 90% of the chickpea area in Andhra Pradesh
- Chickpea performance:
  - ✓ **9-fold** increase in production (95,000 to 884,000 tons)
  - ✓ **5-fold** increase in area (102,000 to 602,000 ha)
  - ✓ **2.4-fold** increase in yield levels (583 to 1,407 kg/ha)

Interventions

- Across India, 43 high-yielding chickpea varieties with early to medium maturity and high resistance to wilt have been developed and released in India through ICRISAT partnership with State Agricultural Universities.
- High adoption in central and southern India
- Accounted for about 49% of the total indent of chickpea breeder seed in India (2013-14)
- Chickpea variety NBeG 47, the first machine harvestable variety released in Andhra Pradesh suitable for the state's variable climate

Crop Improvement: First ever Pigeonpea Hybrids

Impacts

- 30-40% yield advantage in farmers' fields under rainfed and irrigated ecosystems.
- 10 commercial hybrids (3 from the public sector and 7 from the private sector) being released in India
- Area under cultivation increased from 40,000 ha (2013) to 127,3 ha (2015) due to collaborative efforts
- 200,000 ha expected to be covered in 2016

Interventions

- A first-ever legume hybrid developed by CRISAT and Indian partners was developed for pigeonpea, using new breakthroughs in science. The new hybrids along with dedicated efforts to work with private industry led to the seeds being commercially available.
- Identified male sterile sources and developed heterotic hybrid combinations with resistance to fusarium wilt and sterility mosaic disease
- Parental lines shared with public and private partners to strengthen their efforts in hybrid breeding and to develop high-yielding hybrids for different agro-ecologies.
- Seed production technology standardized to harvest appreciable quantities of hybrid seeds from the female parent.

Crop Improvement: Early-maturing Groundnut

Interventions

- Through farmer participatory varietal selection, a groundnut variety (ICGV 91114) was identified as a farmer preferred variety and released in three states in India -- Andhra Pradesh, Odisha and Karnataka.

Impacts

- On-farm impact study on adoption of the new groundnut variety in Ananthapur district of Andhra Pradesh showed:
  - **23%** increase in pod yield
  - **36%** higher net incomes
  - **30%** reduction in yield variability
  - Study by International Livestock Research Institute (ILRI) showed 11% increase in milk yield when cereal fodder is supplemented with ICGV 91114 compared to TMV 2
  - National breeder seed indent for ICGV 91114 for ICGV 91114 accounted for 14% of total indent for all the varieties during (2014), indicating the growing popularity

Crop Improvement: Extra-early Pearl Millet Hybrid

Impacts

- Improved varieties grown on >875,000 ha, largely in the drought-prone areas of Rajasthan
- Net income from improved seed: earned a net income of USD 1460/ha; total net benefit: of USD 6.4 million in 2011
- Seed multiplication generated 186 person days /ha of employment
- Net improved benefits of USD 13.5 million in 2011 alone, compared to previous varieties
- Generated 900,000 days of employment each year, 45% of whom were women laborers

Interventions

- Inter-institutional collaboration integrated conventional, participatory and marker-assisted breeding methods to develop extra-early pearl millet hybrid HHB 67 Improved, which has enhanced downy mildew resistance and yield.

Impacts of ICRISAT'S work in Africa

Developed Seed Industry in **Malawi**

2.2 million

Households reached directly

10-fold increase

In groundnut foundation seed production

1400 kg sorghum seed

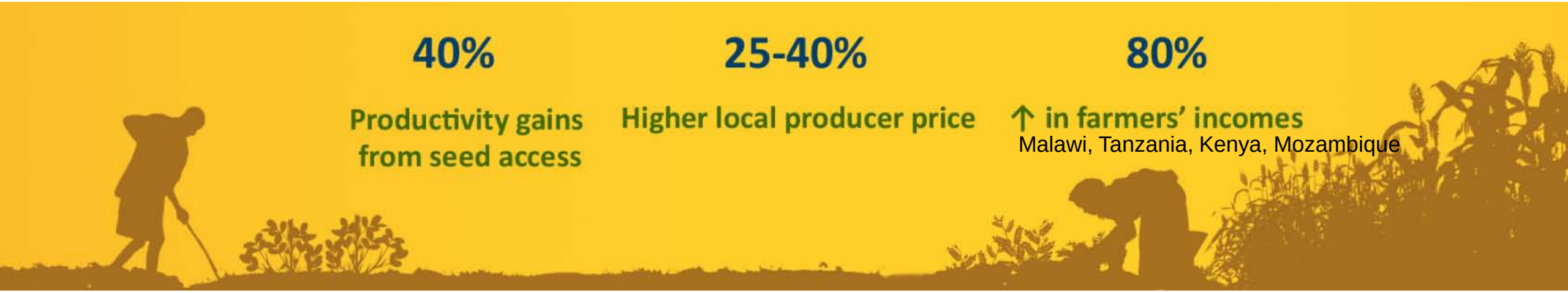
Contribution to Malawi government

Developed Seed Industry in **Malawi**

Impacts

- 2 million households reached directly
- 4,500 tons or 54% of seed: Contribution to the Farm Input Subsidy Program (FISP) of the government in 2013
- The 2013 seed infusions into the FISP translate into:
  - US$ 5.7 million per annum from seed and grain sales
  - US$ 3.3 million worth of consumed legumes and grain in households
  - 10-fold increase (42 tons in 2008 to 400 tons in 2014) in groundnut foundation seed production
  - 8308 tons of improved groundnut and pigeonpea seed sold by the private sector local seed companies through the FISP
  - 1400 kg of sorghum seed: ICRISAT's contribution to the Malawi government for the 2015-2016 cropping season
  - Benefited neighboring countries Tanzania, Zambia and Mozambique.

Promoting pigeonpea in **Eastern and Southern Africa**



- Access to ever growing Indian grain market through trader participation
- Over 15 large-scale *dal* processing plants set up in Malawi, Tanzania, Kenya and Mozambique
- Production and dissemination of 4,250 tons of quality seed covering about 0.5 million ha in the last 8 years
- Hybrids are now being developed for ESA for uptake by seed companies with a 30% yield advantage over improved varieties

Promoting pigeonpea in **Eastern and Southern Africa**

Impacts

- 40% productivity gains from greater access to superior seed (1309 kg/ha in Malawi)
- Access to ever growing Indian grain market through trader participation
- Over 15 large-scale *dal* processing plants set up in Malawi, Tanzania, Kenya and Mozambique
- 25-40% higher local producer prices in ESA following producer-wholesaler linkages
- Production and dissemination of 4250 tons of quality seed covering about 0.5 million ha in the last 8 years
- 80% rise in farmers' incomes in Kenya, Malawi, Mozambique, Tanzania and Uganda
- Hybrids are now being developed for ESA for uptake by seed companies with a 30% yield advantage over improved varieties

Finger millet in Eastern Africa

- More income to farmers from seed production (1.5 times the price of grain)
- 40% yield increase in farmers' fields with improved varieties and an additional 20% increase with appropriate agronomic packages
- Community seed production units started in Ethiopia, Kenya, Tanzania and Uganda, with women being the main producers
- Availability of greater diversity of finger millet products leading to increased consumption.

Nutritional facts

- 340mg/100g **Calcium**
  – 3 times more than milk

High **Iron** (75mg/kg)

High **Folic acid** (46mg/100g)

HOPE – for **Sorghum** and **Millets** in Sub-Saharan Africa and South Asia

Impacts

- **Sorghum productivity gains 21% in Nigeria to 129% in Mali**
  from the whole package of improved practices in harsh environments of Western and Central Africa ranged from.
- **Pearl millet productivity gains 50% in Mali to 150% in Niger**
- Use of **fertilizer microdosing** with improved varieties, resulted in:
  average yield increases of > 130% in West Africa
  profits increasing > 60% in East Africa.

Recent **Impact Assessment** examples

- **Fertilizer Microdosing in Zimbabwe** – IRR = 45%
  NPV of benefits of over US$33 million over 20 years

- **Sorghum improvement in Mali** – IRR = 36% per year
  Benefit-cost ratio = 6:1

- **Improved pigeonpea in Tanzania** – IRR = 21.9% to 25.5%,
  Benefit-cost ratios = 4.9 to 6.8.
  Net social benefits = US$1.03 million to US$5.06 million
  (the largest proportion accruing to consumers)

Thank **You**

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