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

47th Annual Group of AICRP on Sorghum
17 Sustainable Development Goals with emphasis on sustainable and equitable food systems
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
High levels of poverty, malnutrition and environmental degradation

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
Specialization in crops suitable for the drylands

- Sorghum
- Pearl millet & Finger millet
- Groundnut
- Chickpea
- Pigeonpea

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

Our Team
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

Market-driven Innovation

- Analyzing key problems and opportunities
- Managing soil and water
- Crop Improvement & seed Access
- Diversifying Farms
- Developing on-farm practices and technologies
- Introducing processing
- Facilitating market access
- Driving market development

Building Agribusinesses

Sustainable Intensification

Value addition & Market integration offers >100% increase in farmer incomes
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. Biofuels, Fodder

**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 Foods: Nutri-Cereals

WHY DRYLAND CEREALS?

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

DEMAND

40% By 2020 demand for dryland cereals in target regions will increase by about 40%
- IFPRI IMPACT MODEL

YEAR 2020

USAGE

HUMAN FOOD (40%)
Human consumption contributes to 40% of farm gate value

EMERGING USES (10%)
Growing interest in the use of dryland crops for industrial uses contributes to 10% of farm gate value

ANIMAL FEED (50%)
Feed and fodder use contributes to 50% of farm gate value

Farm gate value of Dryland Cereals in LIFDCs is US$ 27.3 billion

TARGET CROPS AND COUNTRIES

BARLEY

Ethiopia | India | Iran
Kazakhstan | Morocco | Turkey

FINGER MILLET

Ethiopia | Tanzania
Uganda

PEARL MILLET

Burkina Faso | India | Mali
Niger | Nigeria | Senegal
Sudan | Tanzania

SORGHUM

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

**Integrated Breeding Program**

- **Research Programs**
  - Asia, ESA, WCA
  - Crop Improvement
  - Int. Crop Management
- **Breeding Population**
  - Breeding Population
  - Selfing and selection
  - Advanced breeding lines
  - Parental lines
- **Tools & Technologies**
  - Diversity
  - Trait specific lines
  - Phenotyping
  - Tools & technologies
  - Induced variations
- **Research Program Genetic Gains**
  - Genebank
  - Pre-breeding
  - Genomics & Trait discovery
  - Forward Breeding
  - Cell, Molecular Biology & Genetic Engineering
- **Research Program Innovation System for the Drylands**
  - MIND analysis to maximize outcomes
  - Systems analysis for Climate Smart Agriculture
  - Mapping homologous environments to target varieties/ quantity of seed
  - Agribusiness and Innovation Platform

**Knowledge Platform for Innovative Seed Systems**

- NARS/ Pvt Sector
  - Varieties
  - Hybrids
  - Farmers fields
Genetic diversity and population structure

296 Sets and 36 countries seven crops

Breeders

Farmers

Diversity on farm

Large Number
Eg groundnut 15,445
Limited data
Low use

Less number
Eg groundnut 1,704
Limited evaluation
Molecular character
Moderate Use

Limited number
Eg groundnut 184
Extensive evaluation
Molecular characterization
Genetic diversity
Population structure
High Use

Core collection
(100%)

Entire collection

Core collection
(10%)

Mini core collection
(1%)
## Mini-core collections of germplasm at ICRISAT

<table>
<thead>
<tr>
<th>Crop</th>
<th>Entire collection</th>
<th>Mini core number</th>
<th>% of entire Traits used</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td>16,991</td>
<td>211</td>
<td>1.24</td>
<td>Upadhyaya and Ortiz 2001; TAG 102:1292-1298</td>
</tr>
<tr>
<td>Groundnut</td>
<td>14,310</td>
<td>184</td>
<td>1.28</td>
<td>Upadhyaya et al. 2002; Crop Sci. 42: 2150-2156</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>12,153</td>
<td>146</td>
<td>1.20</td>
<td>Upadhyaya et al. 2006; Crop Sci. 46:2127-2132</td>
</tr>
<tr>
<td>Sorghum</td>
<td>22,473</td>
<td>242</td>
<td>1.08</td>
<td>Upadhyaya et al. 2009; Crop Sci. 49:1769-1780</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>20,844</td>
<td>238</td>
<td>1.14</td>
<td>Upadhyaya et al. 2011; Crop Sci. 51 :217-223</td>
</tr>
<tr>
<td>Finger millet</td>
<td>5,940</td>
<td>80</td>
<td>1.34</td>
<td>Upadhyaya et al. 2010; Crop Sci. 50: 1924-1931</td>
</tr>
<tr>
<td>Foxtail millet</td>
<td>1,474</td>
<td>35</td>
<td>2.37</td>
<td>Upadhyaya et al. 2011; Field Crops Research 124:459-467</td>
</tr>
</tbody>
</table>
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: 14 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)
- Mungbean (Nature Commun 2014)
- Sesame (Genome Biology- 2014)
- Pearl millet- 2017 (in revision)
Partners

The 3000 Chickpea Genome Sequencing Initiative

Sequencing data already generated

Genome architecture of the 3000 lines

Improved chickpea lines
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)
Identify new alleles for crop improvement

- 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

Tanksley and McCouch 1997

~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

- 20-30 crosses
- 6,000-10,000 Plant architecture
- 5,000
- 3,000
- 1,000
- 500
- 50
- 50 entries to regional trial
- recommended variety

(disease, days to flowering, plant stand etc)

Selection intensity \((i)\) : Low
Selection efficiency \((r)\) : Low
Genetic variance \((\sigma)\) : Low
Years per cycle \((Y)\) : High
Early generation screening for **must-have** traits

- **F2**: 200,000
  - Screening for disease, plant habit, quality, yield etc.

- **F3**: ~5,000 homozygous lines based on allelic contributions

- **F4**: ~1000 single plant selection based on other morphological traits

- **F5**: ~50 entries selected based on replicated multi-location/station trials

- **F6-8**: ~5-10 superior breeding lines recommended as variety for targeted traits
  - MAS for homozygocity test
  - DNA fingerprinting

**Selection intensity (i)**: High
**Selection efficiency (r)**: High
**Genetic variance (σ)**: High
**Years per cycle (Y)**: Low

\[ R_t = \frac{ir\sigma}{Y} \]
High-throughput low-cost genotyping

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

Target Samples/ year:

<p>| | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>CIMMYT</td>
<td>300,000</td>
</tr>
<tr>
<td>ICRISAT</td>
<td>240,000</td>
</tr>
<tr>
<td>IRRI</td>
<td>150,000</td>
</tr>
<tr>
<td>IITA</td>
<td>50,000</td>
</tr>
<tr>
<td>CIAT</td>
<td>25,000</td>
</tr>
<tr>
<td>CIP</td>
<td>25,000</td>
</tr>
<tr>
<td>AfricaRice</td>
<td>25,000</td>
</tr>
<tr>
<td>Target crops</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
</tr>
<tr>
<td>Chickpea</td>
<td></td>
</tr>
<tr>
<td>Groundnut</td>
<td></td>
</tr>
<tr>
<td>Common bean</td>
<td></td>
</tr>
<tr>
<td>Cowpea</td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td></td>
</tr>
<tr>
<td>Sweet potato</td>
<td></td>
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<tr>
<td>Potato</td>
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</table>
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

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

*Efforts have been initiated by Illumina
Genome to fields - **FASTER**!

1. Improved lines with enhanced yield in chickpea

![Yield Graph]

- 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

- TAG 24
- TAG 24 + rust QTL
- GP8D 4

- Susceptible line
- Resistant introgression line
- Resistant line

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

4. Improved lines for high oleic acid in groundnut

- improved lines up to 80% oleic acid
ICRISAT has built a large network of delivery partners capable of identifying and equipping lead farmers...

...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

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

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

Pyramid of Economic Opportunity

- >500 million
- Local storage $$
- Local value addition $$$$
- 100s
- International processors and markets
- National processors
- National warehouses
- National aggregators
- Regional aggregators
- Local aggregators

45 FORISAT
Value Chains and Country Strategies

- Demand-driven innovation
- Backward integration of farmers to markets

Research and development
- Discovery
- Crop improvement
- Agronomic research

Inputs and farmer services
- Seed systems
- Other input systems
- Farm management
- Knowledge exchange

Post-harvest handling and access to markets
- 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

Addhaar: Unified Payment Interface

Spatial Data Infrastructure: High resolution base maps to integrate in time and space

- National Farmer database
- Finance Dept.
- Monitoring and Evaluation Engine
- Planning and Budgeting
- International Commodity Markets
- Artificial Intelligence Engine
- Agriculture Input Markets
- FPOs, VC services and farmer dashboards

- Market Information (Prices)
- RT down-scaled weather data
- Digital soil maps
- Hydrology data
- Socio-economic + health data
- Value Chain Logistics
- Infrastructure and Logistics
- Crop recommendations
- Fertilizer recommendations
- Policy recommendations

FPOs, VC services and farmer dashboards to increase farmer incomes and reduce risk

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

**Research groups**
- Breeders
- System modelers
- Social scientists
- Hydrologists
- Planning departments

- Crop type / intensity maps
- Land use changes
- Length of growing periods
- Abiotic
- Water productivity
- Spatial modeling (Prioritization)
- Impact assessment
- Simulated yield estimations and impact
- Tracking adoption of NRM Technologies
- Impact assessment

- Abiotic stresses
- Water productivity
Cropland classes

ICRISAT Crops
- **Sorghum**
- **Millets**
- **Groundnut**
- **Pigeonpea**
- **Chickpea**

- **Kharif + Rabi sorghum (4.32 Mh)**
- **Groundnut (0.8 Mha)**
- **Groundnut (1.67 Mha)**
- **Millet (5.35 Mha)**
Thank you
Selected Impacts of ICRISAT’s work
Holistic Scaling-up in Karnataka

**Impacts**
- 4.75 million farmers have benefited over 5 years
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Crop Improvement: Chickpea in Andhra Pradesh and Telangana

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

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)
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 accounted for 14% of total indent for all the varieties during (2014), indicating the growing popularity
Crop Improvement: Extra-early Pearl Millet Hybrid

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

- 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

Seed multiplication generated 186 person days /ha of employment
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