Review Meeting
Dryland Cereals Phase 1 and Extension Phase

Improving food security and incomes with productive, nutritious multi-purpose pearl millet hybrid production technologies for East Africa and South Asia

Pearl millet hybrids for East Africa and South Asia

Presenting on behalf of scientists involved in pearl millet research (ICRISAT and partners)
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Date: 4 October 2016

http://drylandcereals.cgiar.org

A global alliance for improving food security, nutrition and economic growth for the world’s most vulnerable poor
Pearl millet hybrids for East Africa and South Asia

### Target countries

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Area (m ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>India</td>
<td>8.5</td>
</tr>
<tr>
<td>ESA</td>
<td>Sudan</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Tanzania and Uganda</td>
<td>0.5 each</td>
</tr>
</tbody>
</table>

### Regional production, yield and area trends (1981-2010)

<table>
<thead>
<tr>
<th>Region</th>
<th>Production</th>
<th>Yield</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>1%</td>
<td>5%</td>
<td>-4%</td>
</tr>
<tr>
<td>ESA</td>
<td>5%</td>
<td>0%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Hybrids occupy 5-6 m ha in India, while ESA cultivates OPVs.
Pearl millet hybrids for East Africa and South Asia

- **R4D Challenges in India**
  - Higher productivity - highest priority trait in regions with 400-700mm/annum rainfall
  - Increasing genetic diversity in regions with <400mm annum rainfall

- **Major challenges:**
  - *Biotic:* Downy mildew, Blast
  - *Abiotic:* Heat tolerance, Drought adaptation
  - *Others:* CMS diversification, forage pearl millet, biofortification, up scaling of crop management technologies, low shelf life of flour, increasing demand through improved processing

- **R4D Challenges in ESA**
  - Identification of hybrids and their release
  - Seed production systems for pearl millet hybrids
Objectives 2012-16

- Overarching Goal
  - Increase in pearl millet production of 0.9 m tons over a period of 5 years in ESA and SA (Indian states of Gujarat, Haryana, Rajasthan, Maharashtra, and Uttar Pradesh) with 1.02 m ha increase in area

- Outcomes
  - Knowledge generation on trade-offs between different traits and state/country specific cultivar characterization
  - Increasing genetic and cytoplasmic diversity of hybrid parents coupled with disease resistance
  - Increasing availability of hybrid parent for adaptation to drought, flowering stage heat stress and salinity affected environments
Objectives.....

- **Outcomes**
  - Strengthening breeding program on high biomass forage type plant types
  - Improving grain Fe content of hybrid parents
  - Identification of crop management practices for upscaling
  - Improving seed systems in ESA region and in drought prone environments of SA
  - Identify processing technologies and value added products to increase market value of crop.
PEARLS

- Pearl millet genome sequenced
- Analysis of future demand scenario of millets; prioritization of traits
- Increasing genetic diversity and enhancing blast resistance
- Identified hybrids and management practices for drought prone environments, and elevating tolerance for heat stress at flowering period
- Forage type cultivars and hybrid parents; and bio-fortification of pearl millet grains (high Fe)
- Pearl millet genomics and molecular breeding
- LeasyScan differentiates pearl millet material bred for different agro-ecologies
- Hybrids for ESA
- Determination of variability in rancidity profile of select commercial pearl millet varieties/hybrids
- Commercializing dry land cereals through product development, scientific validation and entrepreneurship
Pearl millet genome sequenced!

- Consortium of multiple partners was formed
- Tift 23D2B1, the global reference genotype sequenced
- Hybrid sequence assembly approach (whole genome shotgun sequence (WGS) data and BAC sequencing data together with a restriction site associated DNA (RAD) sequence tag based genetic map)
- Re-sequencing of 993 pearl millet breeding lines by using whole genome re-sequencing (WGRS) and/or RAD-sequencing completed

To be published soon

http://ceg.icrisat.org/ipgsc.html
Analysis of future demand scenario of millets

Millet demand in SA and ESA, 2010-2050 (IMPACT model)

Millet food, feed and other demand in India, 2010-2050

Figure A3-6. Trends in aggregate demand for sorghum and millets, 2010-2050

Nedumaran et al. 2014
Prioritization of pearl millet research segments in India and trait prioritization

Result 1: Present investment proportion by the organizations in India for different pearl millet segments

- 57, 24, 16, 15, and 8 percent of market investment is occurring on rainy season hybrids, summer season hybrids, hybrids for drought prone environments, exclusive forage hybrids and high grain-Fe hybrids, respectively
Increasing genetic diversity

<table>
<thead>
<tr>
<th>Description</th>
<th>Field Day Year</th>
<th>Public</th>
<th>Private</th>
<th>Total</th>
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<tr>
<td>Number of unique lines selected</td>
<td>2012</td>
<td>712</td>
<td>2484</td>
<td>2782</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>1283</td>
<td>1240</td>
<td>2523</td>
</tr>
<tr>
<td>Number of samples supplied</td>
<td>2012</td>
<td>1304</td>
<td>4941</td>
<td>6245</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>3429</td>
<td>2071</td>
<td>5500</td>
</tr>
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</table>

**ICAR-ICRISAT Collaboration**

45 breeding nurseries comprising of about 1100 hybrid parents were evaluated at AICPMIP centers and promising trait and adaptation-specific breeding lines were selected during 2012-2015.

Clustering of 122 hybrids into 7 distinct clusters, highlights the successful efforts of national program of pearl millet improvement toward genetic diversification of hybrids.

Yadav et al. 2016
Enhancing blast resistance

- Pathotypes of pearl millet infecting populations of the pathogen (*Magnaporthe grisea*) identified
- Resistance sources to these pathotypes identified
- New wave of blast resistant breeding materials generated
- Three sprays of fungicide, Nativo @ 0.4 g/l or Tilt @ 1 ml/l were found effective in controlling blast
- Promising *P. violaceum* accessions identified and utilized as donors and pearl millet germplasm lines/hybrid parents as recipients to generate interspecific crosses
Hybrids and management practices identified for drought prone environments in Pearl Millet

- About 25,000 farm households were provided with seed of improved hybrids and balanced fertilizer during 2010-2015

- Increased pearl millet yield from 30 to 100% across various rainfall, soil and agro-ecological regions of Rajasthan, Haryana and Gujarat

- Seed production Scaled-up for identified hybrids and their parents: RHB 177, MPMH-17, HHB 226, GHB 538, B70, JKBH 676

- Management practices identified: Weedicide application, pest management (white grubs) and micronutrient (ZnSO4) demonstrated 14-24%, 7-14% and 11-19% yield increase, respectively, over control.

<table>
<thead>
<tr>
<th>State</th>
<th>Yield (t/ha) 2009</th>
<th>Area (ha)</th>
<th>Yield (t/ha) 2013</th>
<th>% Yield Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajasthan</td>
<td>0.76</td>
<td>3317</td>
<td>1.66</td>
<td>118</td>
</tr>
<tr>
<td>Haryana</td>
<td>1.54</td>
<td>3244</td>
<td>2.02</td>
<td>31</td>
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<tr>
<td>Gujarat</td>
<td>1.07</td>
<td>2560</td>
<td>2.30</td>
<td>115</td>
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</table>
Elevating tolerance for heat stress at flowering period

- 13 B-lines, 2 R-lines, 1 germplasm accession and 2 populations identified with high seed set at air temperatures of >42°C during flowering
- New breeding lines developed having higher heat tolerance levels

*Field Crops Research, 2015, 171, 41-53*
Forage type cultivars and hybrid parents

- High stover yield germplasm identified from germplasm
- Forage type A-/B- pairs and R-lines developed
- Forage type breeding lines and Composites developed
- Forage type Top-crosses and 3-Way crosses under investigation

<table>
<thead>
<tr>
<th>S.no</th>
<th>Entry</th>
<th>OPVs/ Germplasm</th>
<th>Hybrids</th>
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<tbody>
<tr>
<td></td>
<td>Fresh Stalk Yield (tons/ha)</td>
<td>Fresh Stalk Yield (tons/ha)</td>
<td>Fresh Stalk Yield (tons/ha)</td>
</tr>
<tr>
<td></td>
<td>Fresh Dry Stalk Yield (tons/ha)</td>
<td>Dry Stalk Yield (tons/ha)</td>
<td>Fresh Dry Stalk Yield (tons/ha)</td>
</tr>
<tr>
<td></td>
<td>Gujarath</td>
<td>MP</td>
<td>Pooled</td>
</tr>
<tr>
<td>1</td>
<td>ICMV 05222</td>
<td>58.1</td>
<td>27.3</td>
</tr>
<tr>
<td>2</td>
<td>ICMV 05777</td>
<td>51.8</td>
<td>23.2</td>
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<tr>
<td>3</td>
<td>IP 6107</td>
<td>47.0</td>
<td>21.0</td>
</tr>
<tr>
<td>4</td>
<td>ICMA 00444 X IP 6202*</td>
<td>96.7</td>
<td>39.8</td>
</tr>
<tr>
<td>5</td>
<td>ICMA 09888 X IP 11431*</td>
<td>89.7</td>
<td>35.7</td>
</tr>
<tr>
<td>6</td>
<td>ICMA 09888 X IP 13150*</td>
<td>85.0</td>
<td>33.3</td>
</tr>
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</table>

*Evaluated during rainy 2015 in Gujarat and MP over 100 (43) farmer fields
Evaluated during 2014 and 2015 in Gujarat and MP over 164 (76) farmer’s fields
Bio-fortification of pearl millet grains (high Fe)

- More than 200 high-Fe breeding lines and hybrid parents supplied to NARS partners
- More than 5000 grain samples from AICPMIP were analyzed for Fe/Zn content
- Screened >1000 mainstream breeding line for high-Fe/Zn content
- Mainstreaming of biofortification breeding: >50 high grain Fe hybrid parents (seed and pollinator) were used to introgress high micronutrient traits into high yielding and agronomically desirable backgrounds.

High-iron pearl millet cultivars

*Funding: HarvestPlus (A4NH)*
Pearl millet genomics and molecular breeding

1. Two popular hybrids improved for downy mildew resistance (GHB 538, and HHB 67 second cycle improvement)

2. Popular hybrid HHB 146 improved for foliar blast resistance by transferring major blast resistance QTL, for possible release in the state of Haryana

3. High-density consensus linkage map developed by saturation the linkage maps of four pearl millet RILs

4. Mapped large effect QTLs for virulent downy mildew isolates from Gujarat, Rajasthan and Haryana

5. Towards heterotic gene pool formation
Leasy Scan differentiated Pearl millet material bred for different Agro-ecologies

Eco-types vary for water stress adaptation

A1-severe drought
A-mild drought
B-rare drought

Opportunity to harness traits controlling plant water use, of critical importance for drought adaptation, towards the breeding of improved varieties

Leasy Scan developed to assess canopy traits affecting water use (leaf area, leaf area index, transpiration)
Hybrids identified for ESA

- **ESA hybrids evaluation**
  - Hybrids evaluated in ESA countries in two seasons during 2012-2014
  - Four hybrids selected for PVS
  - Second season included 25 OPVs and 25 hybrids
  - Hybrids had yield superiority over 20-40% over local checks
  - Now, seed production of identified hybrids in ESA itself

![Graph showing grain yield comparison between OPVs and Hybrids](OPVs_Hybrids.png)
Variability in rancidity profile of select commercial pearl millet varieties, hybrids and hybrid parents

- 56 commercial pearl millet varieties/hybrids/hybrid parents profiled for peroxide (PV) and acid (AV) values under accelerated (35°C & 70% RH) conditions
- Wide variability observed in the overall rancidity profiles (Fig 1).
- 13 pearl millet varieties/hybrids least susceptible to rancidity identified (Fig. 2).

Fig 1: Rancidity profile of pearl millet varieties/hybrids under accelerated storage.

Fig 2: PV and AV (10th day) values of Pearl millet varieties/hybrids showing least susceptibility towards rancidity.
Commercializing dry land cereals through product development, scientific validation and entrepreneurship

- Millet based products developed and validated on content and claims of products.
- An eco-system to generate market demand for dryland cereals established and implemented (Fig. 1).
- Products successfully commercialized (Fig. 2) through support to SMEs.

Fig 1: Eco-system at the Agribusiness and Innovation Platform (AIP), ICRISAT to promote dryland cereals through product development, scientific validation and entrepreneurship.

Fig 2: Enterprises promoted linked to validated millet based products and impacts.
IMPACT

- About 60% area of pearl millet in India covered under hybrids based on ICRISAT-bred hybrid parents (2006, 2010, 2015 IA studies)
- DT hybrids up-scaled in drought prone environments: 3000 quintals seed produced by different agencies in 2015 and 2016
- Biofortified cultivars up-scaled: 50,000 ha
Third party evaluation study to assess ‘On-farm impact of pearl millet HPRC hybrids’ during 2015

Covered 563 pearl millet growers covering three states (Rajasthan, Gujarat and Uttar Pradesh) in India

HPRC hybrids covered >50% of pearl millet hybrid area in 3 states during 2013-14.

HPRC hybrids provided at least 20% higher yields than replaced cultivars

Total benefits accrued will surpass $150 m/year, if coverage in other states are considered.
Lessons Learned

- Seed production is not the end of seed chain in upscaling cultivars
- Genome sequencing information needs solid platforms to utilize information
- Forage quality traits needs balancing with yields
- Range of food products can be developed in labs but public awareness required to upscale along with right partners
- Need to identify right gaps related to mechanization of farm operations and economical solutions
Areas suggested for continued R4D

- Genome is sequenced, utilization of information, genomic selection to be part of breeding programs
- Hybrids to be established in ESA region, strengthening of seed sector
- Diversification of hybrid parents: New germplasm from Africa and vice versa
- New breeding materials to develop hybrids for drought affected A1 zone
- Heat tolerant material to strengthen summer cultivation
- Biofortification - micronutrient traits to be mainstreamed
- Forage type hybrids - monitor fodder quality traits in cultivar testing/release process
- Flour rancidity – combined approach (processing, genomics, and breeding)
- Food products – smart food campaigns and up-scaling
- Strengthening of Double Haploid technology
Projects funded by..

- CRP-DC
- HOPE
- PMHPRC
- PM Genome Sequence Consortium
- USAID
- Indo-US-JCERDC
- MoA, GOI
- Harvest Plus
- Sehgal Foundation
- DBT
## List of Posters: 6

<table>
<thead>
<tr>
<th>Title</th>
<th>Author List</th>
</tr>
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<tbody>
<tr>
<td>3. Increasing pearl millet productivity in drought-prone environments of north western India</td>
<td>Rajan Sharma¹, SK Gupta¹, PS Shekhawat², HP Yadav³, Anil Kumar³, Devvart Yadav³, DS Shah⁴, BM Patel⁴, Tejas Parekh⁴; D Atkare¹ and M Boratkar¹</td>
</tr>
<tr>
<td>4. Management of the blast disease, an emerging threat to pearl millet production in the semi-arid tropics of India</td>
<td>Rajan Sharma1, SK Gupta1, Shivali Sharma1, HD Upadhyaya1, Sumerpal Singh2 and HR Bishnoi3</td>
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<td>5. Pearl millet breeding for non-conventional traits and ecologies in South Asia (SA) and Eastern and Southern Africa (ESA)</td>
<td>SK Gupta1, and Henry Ojulong2</td>
</tr>
<tr>
<td>6. Vision 2030 for Pearl millet in India: Setting research priorities via consultation process</td>
<td>AK Jayalekha¹, YS Verma², HP Yadav³, SK Gupta⁴</td>
</tr>
</tbody>
</table>
Our team
Presenter’s Note

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SK Gupta

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