Review Meeting
Dryland Cereals Phase 1 and Extension Phase (2012-16)

Increasing breeding efficiency and delivery of improved products and technologies for enhanced productivity frontier of postrainy season sorghum

A Ashok Kumar, on behalf of PL 7 Team
Principal Scientist (Sorghum Breeding)
ICRISAT-Patancheru, India; a.ashokkumar@cgiar.org

4th October 2016

http://drylandcereals.cgiar.org
CoA 7: Multi-purpose postrainy season sorghum hybrid production technologies

- Postrainy season sorghum is prized for food and fodder
- Crop grows on receding soil moisture, affected by drought
- Photoperiod sensitive and cold tolerant cultivars are better adapted
- OPVs are the cultivar options; heterotic hybrids not available
- Bold and lustrous grain without beak and stover with high digestibility preferred
- Shoot fly, aphids, charcoal root rot affects crop yield
- Low adoption rates (20%) resulting in poor yields (600 kg ha⁻¹)
- Limited processing options and marketability
Objectives 2012-16

- Overarching Goal:

  Improving food and fodder availability in the driest regions of South Asia by harnessing improved postrainy sorghum cultivars, production technologies and markets

- Major objectives:
  - To increase the on-farm postrainy sorghum yields by 34% in 10 years time
  - To improve the access to seeds, inputs, crop advisory and markets by farmers
  - To increase mechanization of crop production reducing the drudgery
  - To increase the access to newer breeding lines, hybrid parents and screening tools for NARS
  - To increase the sorghum uptake by processors for value-addition
  - To enhance the uptake of sorghum stover by dairy farmers/industry
Targeting Opportunities for Technology Development and Delivery

**Target area** – Marathwada and Western region in Maharashtra state, India

**Targeted beneficiaries** – 45,000 households

**Partners:** MPKV, VNMKV, IIMR and ICRISAT

**Cultivars:** Parbhani Moti, Parbhani Jyoti, Akola Kranti, Phule Vasudha, Phule Anuradha and Phule Chitra

**Management practices:**
- Fertilizer application; Wide spacing
- Shoot fly and Drought management

**Baselines were established**
Improved PR sorghum varieties and hybrids

• Improved varieties with 20% higher yield and hybrids with 35-40% higher yield than best checks developed
• 20 varieties and 16 hybrids in MLTs across PR sorghum locations
• New A-/B- lines (8) and R-lines (12), varieties (15) adapted to PR season developed and shared
• Genetic base of postrainy sorghum diversified (250 progenies in F₄ and F₅ generations from 700 crosses)

Delivering nutrition with calories (in collaboration with CRP –A4NH)

- Inheritance of grain Fe and Zn in sorghum studied and breeding methods for improving Fe and Zn developed (baseline for Fe 20 ppm & Zn 20 ppm)
- Developed Zn rich (by 30%) cultivars variety (ICSR 14001) and two hybrids ICSH 14001 and ICSH 14002 that also out yielded (by 20%) checks in MLTs
- ICSH 14002 is currently being tested in All India Coordinated Sorghum Improvement Program for its release
- Rapid phenotyping tools (XRF) for Fe and Zn developed. Correlation between XRF and ICP (r=0.9** for Zn and 0.8** for Fe)

Screening techniques fine-tuned for resistance to Sugarcane Aphid, Melanaaphis sacchari

- Nylon net technique could be used to screen sorghum genotypes for resistance to M. sacchari
- Improved PR sorghum hybrids, varieties and parents with aphid resistance identified

Improved shoot fly resistance lines developed


Transferring shoot fly resistance QTLs into elite lines

Introgression lines carrying shoot fly resistance QTL (trichome density and glossiness on SBI 10) showed significantly lower shoot fly dead hearts and higher grain yield.

SPV 1411
Recurrent parent

J-2614
Donor parent

6045-3

6045-16

6045-22

6045-24

6045-29

5125-25

Introgression lines carrying QTL

Sunita Gorthy et al., under development
Host plant resistance to charcoal rot

- Test lines artificially inoculated by inserting toothpick infested with inoculum of *Macrophomina phaseolina*
- % soft rot, number of nodes infected and length of infection at physiological maturity; Lines with <1 internode infection, <5 cm length of infection and <10% soft rot are considered resistant to charcoal rot
- Parbhani Moti, ICSR 93024, N13, CSV 18 R and SPV 1359, M 35-1 and Giddi Maladandi derived lines showed charcoal rot resistance
Most potential antagonistic actinomycetes against charcoal rot in sorghum identified

<table>
<thead>
<tr>
<th>ISOLATE</th>
<th>Extent of charcoal rot (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCA-546</td>
<td>11.40</td>
</tr>
<tr>
<td>BCA-667</td>
<td>4.45</td>
</tr>
<tr>
<td>BCA-696</td>
<td>4.00</td>
</tr>
<tr>
<td>BCA-698</td>
<td>8.87</td>
</tr>
<tr>
<td>CAI-8</td>
<td>16.87</td>
</tr>
<tr>
<td>Control</td>
<td>21.27</td>
</tr>
</tbody>
</table>

Negative Positive

BCA-667

BCA-696

BCA-698

CAI-8

BCA-546
Photoperiod-sensitive genotypes are best bets as planting time is un-predictable in PR season

Panicle harvest index (PHI) and seed weight together can be used as proxies in selecting for reproductive stage cold tolerance in sorghum

A global alliance for improving food security, nutrition and economic growth for the world’s most vulnerable poor

Water stress scenarios; effect on yield

Rabi-sorghum-INDIA (Kholová et al. 2013)

Chickpea-INDIA (Hajarpoor et al. in prep)
**EXAMPLE: Leaf Area variability in S35 introgression of Stg3A / Stg3B QTL**

<table>
<thead>
<tr>
<th>% of parameter change &amp; physiological meaning</th>
<th>stress scenario</th>
<th>grain (kg ha⁻¹)</th>
<th>stover (kg ha⁻¹)</th>
<th>zone</th>
<th>grain (kg ha⁻¹)</th>
<th>stover (kg ha⁻¹)</th>
<th>value estimate (Rs ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>pre-flowering</td>
<td>-86 (-70;0)</td>
<td>160 (39;254)</td>
<td>Central</td>
<td>-71 (-142;28)</td>
<td>259 (130;387)</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>larger canopy</td>
<td>花卉</td>
<td>328 (120;490)</td>
<td>FarSouth</td>
<td>-25 (-203;180)</td>
<td>418 (266;576)</td>
<td>1715</td>
</tr>
<tr>
<td></td>
<td>post-flowering</td>
<td>-127 (-278;0)</td>
<td>410 (294;541)</td>
<td>North</td>
<td>-97 (-212;21)</td>
<td>338 (184;499)</td>
<td>235</td>
</tr>
<tr>
<td></td>
<td>post-flowering-relieved</td>
<td>-143 (-214;-78)</td>
<td>373 (257;452)</td>
<td>South</td>
<td>-67 (-189;8)</td>
<td>385 (240;481)</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>no stress</td>
<td>56 (-46;143)</td>
<td>348 (197;449)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.05</td>
<td>pre-flowering</td>
<td>37 (0;51)</td>
<td>-75 (-127;-15)</td>
<td>Central</td>
<td>34 (-10;51)</td>
<td>-128 (-160;-61)</td>
<td>-130</td>
</tr>
<tr>
<td></td>
<td>smaller canopy</td>
<td>花卉</td>
<td>126 (43;159)</td>
<td>FarSouth</td>
<td>-189 (-223;-129)</td>
<td>-184 (-254;-113)</td>
<td>-965</td>
</tr>
<tr>
<td></td>
<td>post-flowering</td>
<td>61 (-5;119)</td>
<td>-207 (-286;-129)</td>
<td>North</td>
<td>56 (-14;140)</td>
<td>-184 (-248;-102)</td>
<td>-80</td>
</tr>
<tr>
<td></td>
<td>post-flowering-relieved</td>
<td>44 (10;80)</td>
<td>-145 (-180;-101)</td>
<td>South</td>
<td>34 (0;81)</td>
<td>-146 (-194;-84)</td>
<td>-220</td>
</tr>
<tr>
<td></td>
<td>no stress</td>
<td>-32 (-77;16)</td>
<td>-140 (-203;-79)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Trade-off between grain and stover yield**

![CGIAR Research Program on Dryland Cereals](image)

Kholová et al. 2014 (FPB)
A global alliance for improving food security, nutrition and economic growth for the world’s most vulnerable poor

Livestock per capita

“GRAIN type”

“STOVER type”

Sorghum bread

Finding solutions – socio-economics

Dual purpose sorghum; stover/grain demand

Livestock feed

Vikraman et al., in prep

Economic growth for the world’s most vulnerable poor

Map showing livestock per capita with color coding.
 Phenotyping pipeline

“causal phenotype”

TLNo N

LAI k SLN

Root kl

R_int RUE

Δ Biomass

RADN

vpd

≥A ~A

Grain Size & N Grain Number

Grain Yield

“consequential phenotype”

No. of lines phenotyped

Populations (1000s lines)

LeasyScan

Lysimetry

Field

% of lines with desired phenotype

plants with desired phenotype

No. of lines phenotyped

Phenotyping pipeline

“causal phenotype”

TLNo N

LAI k SLN

Root kl

R_int RUE

Δ Biomass

RADN

vpd

≥A ~A

Grain Size & N Grain Number

Grain Yield

“consequential phenotype”

No. of lines phenotyped

Populations (1000s lines)

LeasyScan

Lysimetry

Field

% of lines with desired phenotype

plants with desired phenotype

Phenotyping pipeline

“causal phenotype”

TLNo N

LAI k SLN

Root kl

R_int RUE

Δ Biomass

RADN

vpd

≥A ~A

Grain Size & N Grain Number

Grain Yield

“consequential phenotype”

No. of lines phenotyped

Populations (1000s lines)

LeasyScan

Lysimetry

Field

% of lines with desired phenotype

plants with desired phenotype
Biotechnological Interventions for Sorghum improvement

• Sorghum transgenics for stem borer resistance developed and being evaluated
• Proof of concept developed for high sugar accumulation through genetic engineering
• Sorghum mutant line identified for centromere-mediated genome elimination for Doubled Haploidy (DH) induction
• Inducer lines using chromosome engineering and genome editing technologies being developed for DH
• Pre-integrated Cas9 sorghum lines developed
• *Tnt1* insertional mutant populations being generated for random insertions within sorghum genome to enable efficient forward- and reverse-genetics studies
Validated management practices and introduction of machinery to reduce costs and drudgery

In-situ moisture conservation, wider row spacing, seed treatment, fertilizer application
Value added products and low cost equipment for processing

Dry roties, Roasted sorghum, Sorghum papad, Flour, Rava & Chopped fodder

Cleaning machine, Air screen cleaner, Gravity separator & Fodder chopping machine

Center of Excellence on Sorghum Food Processing at IIMR
## Major achievements of technologies dissemination

### Yield levels (t ha⁻¹)

(Ahmednagar, Pune, Solapur, Parbhani, Beed, Jalna)

<table>
<thead>
<tr>
<th></th>
<th>2009-10</th>
<th>2010-11</th>
<th>2011-12</th>
<th>2012-13</th>
<th>2013-14</th>
<th>Average of five years</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of farmers</td>
<td>6900</td>
<td>10250</td>
<td>8050</td>
<td>8043</td>
<td>8047</td>
<td>41290 - total</td>
</tr>
<tr>
<td>Grain Yield</td>
<td>1.8 (52)*</td>
<td>1.1 (47)*</td>
<td>0.8 (35)*</td>
<td>0.8 (27)*</td>
<td>1.5 (32)*</td>
<td>1.2 (39)*</td>
</tr>
<tr>
<td>Fodder Yield</td>
<td>4.8 (28)*</td>
<td>3.0 (27)*</td>
<td>2.1 (34)*</td>
<td>1.9 (30)*</td>
<td>4.5 (35)*</td>
<td>3.2 (31)*</td>
</tr>
</tbody>
</table>

* Numbers with in the parentheses are percentages over local

Outstanding Partnership Award for Asia 2014
HOPE leads to increased sorghum yields

ICRISAT-HOPE project interventions stymie drought impacts

Unfavorable conditions like a 30% deficit in rainfall and severe drought failed to make a dent in the lives of over 33,000 farmers in the Marathwada and western Maharashtra regions of India thanks to HOPE project interventions like improved cultivars, crop and drought management practices and extension...
Community seed warehouse for seed storage

Sanpurl cluster, Parbhani Dist
Consortium for sustaining OPV seed chain

Innovative partnership of stakeholders
- Farmers (given buy-back guarantee by Mahabeej)
- Govt. Dept of Agril and seed certification agency
- Maharashtra state seeds corporation and certification agency
- MPKV and VNMKV; ICRISAT and IIMR

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of seed produced (t)</th>
<th>Number of farmers reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>300</td>
<td>30,000</td>
</tr>
<tr>
<td>2014</td>
<td>1000</td>
<td>100,000</td>
</tr>
<tr>
<td>2015</td>
<td>1500</td>
<td>150,000</td>
</tr>
<tr>
<td>2016</td>
<td>6000 (Proposed)</td>
<td>600,000 (Proposed)</td>
</tr>
</tbody>
</table>
Costs, Returns and Net Margins from Seed and Grain Production (Per ha)

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Seed Producer</th>
<th>Grain Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input cost</td>
<td>2,235 (11)</td>
<td>1,872 (15)</td>
</tr>
<tr>
<td>Labor cost</td>
<td>7,184 (33)</td>
<td>8,114 (65)</td>
</tr>
<tr>
<td>Machine cost</td>
<td>12,125 (56)</td>
<td>2,497 (20)</td>
</tr>
<tr>
<td>Cost of production</td>
<td>21,544</td>
<td>12,483</td>
</tr>
<tr>
<td>Post harvest and processing costs</td>
<td>3,938</td>
<td>2,243</td>
</tr>
<tr>
<td>Total Cost</td>
<td>25,482</td>
<td>14,726</td>
</tr>
<tr>
<td>Main product yield (qtls)</td>
<td>12.5</td>
<td>6.08</td>
</tr>
<tr>
<td>Value of main product (Rs/qtl)</td>
<td>3,000</td>
<td>2,380</td>
</tr>
<tr>
<td>By product yield (qtls)</td>
<td>47</td>
<td>18</td>
</tr>
<tr>
<td>Value of by Product (Rs/qtl)</td>
<td>400</td>
<td>369</td>
</tr>
<tr>
<td>Gross Returns</td>
<td>56,250</td>
<td>21,199</td>
</tr>
<tr>
<td>Net Margins</td>
<td>30,768</td>
<td>6,473</td>
</tr>
<tr>
<td>Return to cost ratio</td>
<td>2.21</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Note: Figures in the parenthesis indicate % to the total
Impacts on production system and farmers

Improved varieties haven overtaken Maldandi

‘Sakal’ leading paper in Maharashtra 1st October 2016

Dnyashwar Pawar from Kambi village Ahmendnag district of Maharashtra produced ‘Phule Vasudha’ on 5 acres and purchased his dream ‘Bullet’

Received Rs 2,07,500 (grain+fodder)
IMPACT

• Area under improved varieties increased from 32 – 90% in Marathwada and 12 to 46% in western Maharashtra (in project areas)

• Most farmers adopted improved cultivar, optimum seed rate, method of sowing and fertilizer application

• For every farmer we reached directly, other 5 and 6 farmers have been benefitted indirectly

• Overall increase in productivity to the tune of 28% in Marathwada and 35% in western Maharashtra over baseline

• Yield gap reduced by 25-35% and farmers income enhanced by 33%

• Two M Sc and 2 Ph D students trained (2 Women + 2 Men)

• Sorghum added in National Food Security Mission of India

Lessons learned

- Sustaining seed chain is critical for enhancing adoption and the yields
- CBO-VANRAI distributed chaff cutters in villages to better use sorghum stover
- Need to engage institutional credit providers for sustaining the value chain
- Innovations like Warehousing helps farmers to store seed & grain get higher returns
- Training women in all operations in the value chain helps in sustainability
- Value addition, accessing new markets – key for higher returns
- Engaging policy makers critical for sustaining the value chain
Future R & D thrusts

- ‘Ideotypes’ for specific adaptation and machine harvesting
- Heterotic hybrids adapted to various growing environments
- Cultivars with high water-use efficiency and shoot fly resistance (transfer QTLs for shoot fly resistance and stay-green)
- New chemicals, antagonistic actinomycetes to tackle pests and diseases
- Optimizing planting density and production practices for specific
- Innovative ready to use food products and feed formulations
- Scaling the seed consortium and sensitizing policy makers
Contributing Bilateral Projects

- Harnessing Opportunities for Productivity Enhancement (HOPE) for Sorghum and Millets in Africa and South Asia (BMGF)
- Feed the Future Innovation Lab for Climate Resilient Sorghum (USAID)
- Genetic diversification of hybrid parents base in sorghum (Private sector)
- Improving postrainy sorghum varieties to meet the growing grain & fodder demand in India- Phase I & II (ACIAR)
- Commercialization of sweet sorghum as complementary feedstock for ethanol production in sugar mills of Maharashtra, Gujarat and Tamil Nadu (DBT, India)
- Transferring shoot fly resistance QTLs in to elite sorghum lines (DST, India)
- Identification of QTLs for grain Fe and Zn in Sorghum (DBT, India)
- Identification of micronutrients (Fe and Zn) and vitamin A precursor (β-carotene) dense-sorghums for better health in Western and Central Africa (WCA) and Central India (HarvestPlus)
- US-India Consortium for development of sustainable advanced lingo-cellulosic biofuels (US-India JCERDC)
Summary

- Partnership efforts significantly improved the postrainy sorghum on-farm productivity (from 600 to 850 kg ha\(^{-1}\))
- There is sea change in adoption rates - farmers' want new and better; improved seed is quickly adapted
- Specific adaptation and Water management are critical for yield
- Mechanical harvester is demanded everywhere but no perfect machine as on date
- Seed Consortium is highly effective – ‘buyback’ is key
- Nearly 500,000 sorghum farmers benefitted directly and indirectly though our interventions
- Increased uptake of sorghum in urban areas for food and feed
- Stover yield is double that of grain and it price is close to half of grain. So the economic value of stover and grain are same
- Need to enhance the value chain by working with policy makers
List of Posters

- Transforming the postrainy sorghum production systems for enhanced productivity
- Innovative Seed Consortium for thriving the Postrainy Sorghum Seed Chain
- Genetic Inheritance of Sorghum Shoot Fly Resistance
- Identification of QTLs and Genes for grain Fe and Zn concentration in Sorghum
- Marker-assisted backcrossing (MABC) for the development of improved shoot fly (*Atherigona soccata*) resistant sorghum varieties
- Improving charcoal rot tolerance in sorghum
- Guiding crop improvement (genetics-agronomy) in diverse environments: a sorghum case study
Thank you for your attention

DC Team that contributed for this presentation:

MPKV – Sharad Gadakh, Uttam Chavan
VNMKV – HV Kalpande, RL Aundhekar
ICRISAT – Vincent Vadez, Jana Kholova, Rajan Sharma,
Gopalakrishnan, Pooja Bhatnagar, Kiran Sharma

http://drylandcereals.cgiar.org