Progress in

Rajeev K. Varshney & Team
Research Program- Grain Legumes

Asia Regional Planning Meeting
ICRISAT Hqs, Hyderabad
Feb 10-12, 2014
Feeding billions and bringing prosperity in developing countries!!!

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (mha)</th>
<th>Production (mt)</th>
<th>Yield (t/ha)</th>
<th>Value (US $ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td>9.2</td>
<td>6.7</td>
<td>0.73</td>
<td>3.9</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>4.3</td>
<td>3.5</td>
<td>0.81</td>
<td>2.1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>17.0</td>
<td>18.3</td>
<td>1.01</td>
<td>8.2</td>
</tr>
</tbody>
</table>
Making impact on farmers’ fields following IMOD way

Development of improved varieties, seed production, ICM package, sustainable crop production system
Product line 2:
Heat tolerant chickpea, common bean, faba bean and lentil
2.1 Target areas and cropping systems (SC1)
- GIS mapping data status - collected for India, sub-national (district level) data from 1960 – 2010
- Yield simulation study using DSSAT crop model - for RSG 888, Vijay and JG 11 completed

2.2 Phenotyping protocols for heat tolerance and sources of heat tolerance (SC2)
- Field screening for heat tolerance standardized
- In Kenya, 6 heat tolerant lines identified

2.3 Better understanding of physiological mechanisms (SC2)
- Greater pod setting ability in heat tolerant lines
- 15 differentially expressed heat responsive genes

2.4 Interaction between heat and moisture stress (SC2)
- Validated 30 stress responsive genes for heat and drought
- Genome assembly (62.4 Mb) of *F. oxysporum f sp ciceris* and re-sequencing of 70 isolates in progress
2.5 Candidate genes, molecular markers and novel breeding methods for heat tolerance (SC2)

- Genome sequence of chickpea by ICGSC led by ICRISAT
- Association mapping with 10 candidate genes & whole genome resequencing of 300 genotypes
- 1200 MAGIC lines from 8 drought/heat tolerant lines and re-sequenced parents
- Genomic selection (GS) - phenotyping and genotyping data on training population used for testing GS models for four yield related traits

2.6 Combining enhanced heat and dry root rot tolerance and improved grain quality (SC2)

- Two resistant/moderately resistant lines for dry root rot
- Promising heat tolerant breeding lines

2.8 Area under cultivation of heat tolerant cultivars enhanced (SC3)

- 17.9 t of breeder seed produced for JG 14 in India
- On-farm demonstrations - cultivar JG 14 under 17 to 25% higher yield than local cultivars under heat stress
Product Line 3:
Short duration, drought tolerant and aflatoxin free groundnut
3.2 High precision phenotyping tools for drought tolerance traits (SC2)

- Large scale precision phenotyping platform - Leasy-Scan
- One RIL population phenotyped for drought tol traits in Asia and WCA

3.3 New sources of traits related to drought tolerance, aflatoxin resistance and nutritional quality (SC2)

- Three wild *Arachis* species accessions as aflatoxin resistant

3.4 Transgenic events of groundnut with high levels of drought tolerance and resistance to aflatoxin (SC2)

- 3 transgenic events with resistance to water stress
- Several tissue specific promoters isolated for seed specific expression

3.5 Better understanding of mechanisms and genetics of drought tolerance and aflatoxin contamination (SC2)

- Meta-QTL analysis for drought tolerance using 3 pops
- *Aspergillus flavus* sequencing - two strains from toxigenic and non-toxigenic selected for sequencing
3.6 Genomic tools developed and integrated in breeding for drought tolerance (SC2)

- First version of diploid draft assembly of *A. ipaenensis* and *A. duranensis* generated with 1.7 Gb & 1.2Gb respectively
- Cost effective marker assays, genetic maps, association mapping (524 MTAs), MABC lines with rust
- One RIL population for ELS genotyped using 137 SSRs and one RIL population for GRD genotyped jointly by ESA with Tuskegee Univ.
- Tested different GS statistical models for imp traits

3.7 Short-duration, drought tolerant, nutrient dense and low aflatoxin breeding lines/ varieties (SC2)

- ICGV 00351 released in Tamil Nadu (India), 7 other varieties recommended for South Asia & 6 high yielding lines, 4 confectionary lines and 4 drought tolerant lines identified
- Aflatoxin screening -19 varieties in Mali, 8 in three regions of Ghana, 14 lines from 8th IDRGVT and 15 from 7th IDRGVT
- Two germplasm lines 30.8% higher pod yield in drought cond
3.8 Adoption of short-duration, high-yielding groundnut cultivars and integrated crop management practices (SC4)

- High oil containing lines (7 by NARS and 5 ICRISAT bred) for multilocation testing for release

- FPVS: identified one drought tolerant (India), 2 lines (Bangladesh). Evaluated 10 high oil lines India, 6 elite lines in 15 locations at Mali and Nigeria while 44 lines in South Asia

- Conducted on-farm trials and tested intercropping with cereals in Mali and Nigeria. Two varieties released in Nigeria

- Courses: “Integrated crop management and seed production techniques” & “Pre-season training for ESA and stakeholders in Africa”

3.9 Formal and informal seed systems (SC4)

- Improved seeds of foliar resistant lines, elite lines and segregating population to NARS partners

- >20,000 tons seeds

3.11 Capacity of stakeholders (SC5)

- One MSc student and two researchers- 4 months training

- 14 NARS partners trained in phenotyping in West Africa.
The variety selected to release in Zambia
Product Line 4:
High nitrogen-fixing chickpea, common bean, faba bean and soybean
4.1 Factor(s) limiting SNF in different production environments/crops (SC1)

- On-farm demo (30 farmers) in progress at Mahabub Nagar, Raichur and Gulbarga (India)
- Two rhizobia specific to chickpea were evaluated

4.3 Improved sources of SNF with other stress tol (SC2)

- Evaluated 17 salinity tolerant indigenous isolates in greenhouse
- Evaluated and compared nitrogen fixation efficiency under well-watered and drought stressed conditions

4.5 GxE knowledge of SNF in crops-production systems (SC2)

- Phenotyping RIL pop for growth habit, flowering time, shoot weight, root weight and nodule traits to SNF

4.7 Genomic regions/genes associated with high SNF (SC2)

- Phenotyping 26 chickpea accessions for dry shoot wt, dry root wt, dry nodule wt, nodule number and 15N
- Analysis on a total of 143 rhizobial sequences from nodules completed and 3 primers (gyrB, nifK and nodD) developed
4.8 High nodulating and nitrogen fixing indigenous rhizobia identified and characterized (SC2)

- Seven rhizobia specific for chickpea evaluated for its PGP traits in the field conditions
- Assembly of 96 bacterial genome sequences along with gene prediction completed
- Pan genome assembly of *Mesorhizobium* in comparison with other *Mesorhizobium* sequences is in progress

4.9 Efficient mass production technologies for rhizobial strains (SC2, SC4)

- Of the 15 rhizobial inoculants assessed in 5 states, four samples contained rhizobia and nodulated in the plant infection test

4.10 Capacity of partners for high quality Rhizobium inoculum production enhanced (SC5)

- Hands on training on isolation, evaluation and mass production of rhizobia given to 10 technicians from AP & KA
Product line 5: Insect-smart chickpea, cowpea, and pigeonpea production systems
5.1. Insect-plant host-environment interactions (SC1)

- Geographical distribution of insect pests of chickpea and pigeonpea from 1900 to 2012. Recorded 12 new pests/out breaks in pigeonpea while 7 in chickpea.
- Chlorophyll and flavonoid contents increased in pigeonpea in response to water and heat stress.
- Phytophthora blight incidence increased slightly under elevated CO₂.

5.2. Diverse sources of resistance to target pests and information on mechanisms/inheritance of resistance (SC2)

- Identified 28 mod resistant genotypes for Helicoverpa.
- Selected 30 interspecific lines (C. arietinum x C. reticulatum) with low pod damage and antibiosis to the pod borer larvae.

5.3. Interspecific derivatives of chickpea, cowpea, and pigeonpea with high levels of resistance (SC2)

- 4 interspecific lines & 6 wild relatives with low pod damage.
- Several interspecific F₁s by crossing pod borer resistant and cultivated chickpea/pigeonpea cultivars.
5.4 Cultivars with high levels of resistance to target insects through integrated breeding methods (SC2)

- 5 desi and 4 kabuli chickpea lines with lower damage
- 18 (short), 28 (med), and 6 (long) advanced chickpea lines while 15 (short), 53 (med) and 15 (long) pigeonpea lines
- Identified 106 potential lines for adaptive studies in Ethiopia
- Several promising lines for insect resistance developed

5.5 Biosafety of transgenic crops to non-target natural enemies (SC2)

- Significant reduction in cocoon formation and adult emergence of *C. chlorideae* reared on *H. armigera* larvae
- Adult emergence on transgenic chickpea was very low

5.6. Industrial formulations of emulsifiable neem oil & entomopathogens for inundative releases (SC4)

- Ten mod resistant chickpea lines with high yield potential identified from International *Helicoverpa* screening nursery
- Three chickpea lines showed higher yield with resistance/tolerance to *Helicoverpa*
5.7 An IPM system based on rational application of pesticides, agronomic practices, and pest-resistant cultivars (SC2)

- IPM components (such as Pheromone traps) and bio-pesticides (such as HNPV) were shared with the clients and covered at five locations with an area of 50 ha each.

5.8. Capacity of the stakeholders (including genomics and transgenics) and IPM (SC5)

- Two PhD students on screening of thrips and aphid resistance
- Training course on DNA Extraction and PCR for 15 participants (8 females, 7 males) by ESA team with UNZA
- Workshop on phylogenetics for 19 participants (6 females) from 8 countries (18-20 Sept 2013) by ICRISAT-ESA
- Farmers participatory research (>10,000 farmers from several hundred villages, farmers training, flyers/circulars)
Product Line 6: Extra early varieties of chickpea and lentil
6.1 Constraints and opportunities for extra-early chickpea varieties in target areas and cropping systems (SC1)
- Crop modelling: information collected from 6 locations in India and 3 locations in East Africa
- Sampling framework to collect household data developed

6.2 Extra-early diverse germplasm with resistance to key biotic and abiotic stresses (SC2)
- 40 crosses to combine disease resistance and early maturity
- 23 extra-early chickpea lines screened for FW resistance and wild Cicer accessions screened for Ascochyta blight
- In Kenya, 100 F₃ lines & 200 F₅ lines evaluated for agronomic and seed quality traits and resistance to key diseases

6.3 Novel genes for earliness and molecular markers linked to these genes identified (SC2)
- 50 chickpea lines selected for WGRS
- TILLING: 212 SNPs identified in 16 candidate genes
6.4 Extra-early breeding lines with adaptation to different short season env and improved grain quality (SC2)

- Several superior lines identified

6.5 Integrated crop management practices for extra-early varieties of chickpea for short season environments (SC2)

- Identified 19 actinomycetes and 20 other bacteria promising against *S. rolfsii*, which causes collar rot disease in chickpea. Isolate VBI-23 more effective

6.6 Seed availability of extra-early varieties (SC3)

- ~63000 tons seed produced in South Asia, ~11t seed distributed to 1,631 farmers in India
- 40 FPVS trials in South Asia, 43 in ESA, >4169 on-farm demonstrations in India
Product Line 7:
Herbicide tolerant machine-harvestable chickpea, faba bean and lentil varieties

Genetic variability for herbicide tolerance in chickpea
7.1 Scope and implications of the cultivation of herbicide tolerant cultivars and mechanical harvest of legumes (SC1)

- Current varieties not suitable in WANA region for post-emergence herbicides, machine harvest, prevalence to parasitic weeds
- Three countries, Morocco, Tunisia, and Sudan, identified for establishing small-scale seed enterprise.

7.2 Screening methods for tolerance to herbicides and parasitic weeds standardized (SC2)

- Field and glasshouse screening techniques standardized for pre and post emergence herbicide for 2 herbicides
- Field screening technique for 3 post emergence herbicide

7.3 Germplasm sources for tolerance to herbicides and parasitic weeds, and mechanical harvesting (SC2)

- 8 genotypes tolerant to each for pre and post emergence herbicide. 2 wild species genotypes also
- 7 kabuli chickpea identified for machine harvestable trait
- 3 genotypes identified with least phytotoxicity against Klenic
7.4 Candidate genes and molecular markers for herbicide and parasitic weed tolerance (SC2)

- Development of RILs for mapping genes/QTLs
- Two P450 genes enhancing tolerance of chickpea to various herbicides optimized for expression in chickpea

7.5 Breeding lines/cultivars for herbicide tolerance and mechanical harvesting (SC2, SC3)

- >50 crosses for herbicide tolerance using popular cultivars. ICCV 08109 identified for mech. harv. in rainfed conditions
- Chickpea lines combining machine harvest and Ascochyta blight resistance trait

7.6 Crop-specific economical machine harvest systems and integrated weed management module (SC2, SC4)

- ICCV 11604 with 40% higher plant density recorded significantly higher yield than JG 11 at normal density, and on par yield with JG 11 at 20% higher plant density
- Total harvest losses were less in mechanical harvesting of tall genotypes compared to semi-erect genotype JG 11

7.7 Capacity of NARS in research (SC5)

- One PhD student completed doctoral research (India)
Product Line 8:
Pigeonpea hybrid and management practices
8.1 Different CMS systems for hybrid production (SC2)

- Stability of 8 CMS lines tested in ESA
- CMS lines were maintained and tested with African genotypes for identification of R lines
- Marker based hybrid purity kit developed for ICPH 2671

8.2 Genes/QTLs for fertility restoration identified

- Bi-parental mapping population: ICPA 2039 × ICPL 87119
- MAGIC: 28-two way crosses completed and polymorphic markers for hybridity test of F$_1$ plants identified
- NAM population: 10 different F$_1$ combinations generated

8.3 Hybrid parents with resistance to key biotic and abiotic stresses developed and characterized

- 9 A/B lines identified with obcordate leaf shape and tolerance/resistance to SMD and FW; 36 lines for WL
- 1617 lines evaluated for FW, SMD and phytophthora blight. RIL for FW & SMD, 369 NBS-LRRs in pigeonpea genome
- ICPB 2092 showed highest responsiveness to regeneration and Agrobacterium-mediated genetic transformation
8.4 Pigeonpea hybrids with ca. 25% higher yield than the commercial cultivars and with disease/insect resistance

- 39 hybrids and 65 inbred entries under multi-location evaluation of different states of India
- Phenotyping of two interogression lines (Ils)
- Re-sequencing of 10 NAM parental lines completed with 5X to 8X genome coverage

8.5 Seed production systems for hybrid parents and hybrids refined for different agro-ecologies

- Seed road maps under TL-II (Tanzania, Malawi, and Uganda) & SIMLESA (Kenya, Tanzania, Malawi & Mozambique)- >1876 tons
- Marker purity testing kit for additional 5 new hybrids (ICPH 2740, ICPH 4503, ICPH 3762, ICPH 3933 and ICPH 2751)

8.6 ICM technologies for pigeonpea hybrids developed and promoted

- Total of 222 (red Soil) and 190 (black soil) rhizobia like colonies specific to pigeonpea isolated from pigeonpea cultivars
- 216 rhizobia like colonies identified as true rhizobia, specific to the four cultivars of pigeonpea
8.7 Commercial hybrids cultivated on over 100,000 ha.
- 3200 on farm demonstrations for pigeonpea hybrids in 5 states
- Commercial seed production of AXR in progress in 400 hectares

8.8 Post-harvest processing technologies for pigeonpea
- Five pigeonpea genotypes evaluated for different parameters for cooking quality analysis

8.9 Enhanced capacity of stakeholders in pigeonpea hybrid research and seed productions
- Two workshops with a total of 121 participants (110 male and 11 female) for seed prod tech and marker based hybrid purity
- Distributed >12000 copies of farmer friendly literatures
- 42 tons of parental seeds and 114 tons of certified seeds for inbreds supplied to over 8,000 farmer seed growers
- 600 farmer from different states trained on hybrid seed production
- Conducted one training program on pigeonpea in ESA (18 scientists)
Capacity building to make partnership stronger... across PLs, and also RPs, CRPs)

<table>
<thead>
<tr>
<th>Course</th>
<th>Dates</th>
<th>No. of scientists</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern genomics for crop improvement</td>
<td>22 July- 9 Aug 2013</td>
<td>30 (Male-21 &amp; Female-9)</td>
<td>Brazil-1, Egypt-1, Ethiopia-3, Ghana-2, India-13, Mali-1, Mozambique-1, Malawi-1, Nigeria-1, Philippines-1, Senegal-1, Turkey-1, Tanzania-1, Uganda-2</td>
</tr>
<tr>
<td>Plant genetic resources and genebank management</td>
<td>7-12 Oct 2013</td>
<td>17 (Male-14 &amp; Female-3)</td>
<td>India-5, Ethiopia-1, Nepal-1, Tanzania-1, Niger-1, Bangladesh-1, Nigeria-1, Vietnam-1, Uganda-1, Nairobi-1, Zimbabwe-1 &amp; Malawi-1,</td>
</tr>
<tr>
<td>Application of biometrics and bioinformatics tools in crop improvement</td>
<td>4-9 Nov 2013</td>
<td>20 (Male-17 &amp; Female-3)</td>
<td>India (2), Philippines (1), Uganda (1), Mozambique (1), Ethiopia (1), Tanzania (1), Sudan (1), Eritrea (1), Nigeria (1), Niger (2), Kenya (5) and Burkina Faso (3)</td>
</tr>
<tr>
<td>Pre-breeding and crop improvement in legumes</td>
<td>09-20 Dec 2013</td>
<td>25 (Male-24 &amp; Female-1)</td>
<td>India-3, Philippines-2, Bangladesh-1, Senegal-1, Ghana-1, Niger-1, Kenya-2, Tanzania-2, Malawi-1, Zambia-1, Mozambique-1, Lao-3, Myanmar-3 &amp; Nepal-3</td>
</tr>
<tr>
<td>High-throughput phenotyping</td>
<td>Oct 13- Apr 14</td>
<td>6 (Male-2 &amp; Female-4)</td>
<td>Senegal (2), Mali (3) and India (1)</td>
</tr>
</tbody>
</table>
## Performance indicators-2013

### Production and distribution of seeds in Asia in 2013

<table>
<thead>
<tr>
<th>Crop</th>
<th>Breeder Seed (t)</th>
<th>Foundation Seed (t)</th>
<th>Certified Seed (t)</th>
<th>Quality Declared Seed/Truthfully Labeled Seed (t)</th>
<th>Total (in tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td>581.08</td>
<td>4844.2</td>
<td>56258.62</td>
<td>5703.48</td>
<td>67387.38</td>
</tr>
<tr>
<td>Pigeon pea</td>
<td>14.48</td>
<td>99.15</td>
<td>806.7</td>
<td>1352.7</td>
<td>2273.03</td>
</tr>
<tr>
<td>Groundnut</td>
<td>40.45</td>
<td>436.6</td>
<td>1600</td>
<td>390</td>
<td>2467.05</td>
</tr>
</tbody>
</table>

### Number of elite lines/varieties entered in National Performance/Variety Trials across regions

<table>
<thead>
<tr>
<th>Crop</th>
<th>Asia</th>
<th>ESA</th>
<th>WCA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>India</td>
<td>Ethiopia</td>
<td>Kenya</td>
</tr>
<tr>
<td>Chickpea</td>
<td>10</td>
<td>43+80*</td>
<td>2</td>
</tr>
<tr>
<td>Pigeonpe</td>
<td>9</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Groundnut</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>123</td>
<td>5</td>
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</table>
## Performance indicators - 2013

### Number of papers published in 2013

<table>
<thead>
<tr>
<th>Category</th>
<th>Papers published</th>
<th>Papers co-authored with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NARS</td>
<td>Women scientists</td>
</tr>
<tr>
<td>Journal Articles</td>
<td>108</td>
<td>68</td>
</tr>
<tr>
<td>Journal Articles published in e-SAT Journal</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Books and Journal Volumes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Monographs</td>
<td>8</td>
<td>1</td>
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<tr>
<td>Book Chapters</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Conference Proceedings</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Articles published in Intl Newsletters</td>
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<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>148</td>
<td>78</td>
</tr>
</tbody>
</table>
Challenges

- Team building across regions, institutes, disciplines
- Started to learn from crops/ institutes
- Change in work culture to deliver towards output targets from high-end science to applied aspects to downstream applications (the entire value chain) in IMOD way
- Capacity building in different areas- organized many courses, sometimes one scientist was participating in more than one course
- IDOs at CRP level while research questions at technical level
- Logistics in work planning, reporting, etc.
- Administrative challenge
  - CRPDs vs RPDs,
  - PLs vs Focal Points
Summary and outlook

- Significant progress has been made by Asia Team under different PLs of CRP-Grain Legumes (and CRP-A4NH); Invested lot of efforts in capacity building
- Continue to work to deliver towards output targets
- Enhance synergy across regions; encourage research proposals/projects in regions and across regions
- Enhance collaboration among different disciplines (not only in RP-GL but across RPs, CRPs)
- Modernization of crop improvement programme including modern tools, digitalization (e.g. data recording, handling, management), open data, etc.
- Work with scientists to develop work pipeline for coming years (in context of CRP-GL, ICRISAT's Strategy Plan 2020 and Business Plan 2011-2015 following IMOD way)
Many thanks to...

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Dr Myer Mula
Dr P Janila
Dr Shivali Sharma
Dr S Gopalakrishnan
Dr Hari Sudani
Dr P Parthasarathy Rao
Dr G V Ranga Rao
Dr Abhishek Rathore
Dr Trushar Shah
Dr Mahendar Thudi
Dr Rachit Saxena
Dr Manish Pandey
Dr Pawan Khera
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Dr Emmanuel Monyo
Dr Patrick Okori
Dr Sam Njoroge
Dr NPV Ganga Rao
Dr Damaris Odoney
Dr Chris Ojiewo
Dr Anita Seetha

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Dr CLL Gowda, DDG-R
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... and all partners & donors!!!