NGP Rao Memorial Lecture

(Coinciding with his 93rd Birthday Celebrations)

Dr. NGP Rao

Future of Sorghum and Millets

Raj Paroda

Neelamraju Ganga Prasada Rao

(5 Sept 1927 – 27 July 2016; **88 years**)

- **A highly distinguished Plant Breeder – Par excellence**
- **Known as: 'Father of Hybrid Sorghum'**
- **Became first Sorghum Project Coordinator in 1969,**
  Vice Chancellor, MAU, Parbhani and later Chairman, ASRB
- **Recipient of prestigious ICAR Rafi Ahmed Kidwai Award,**
  VASVIK Industrial Research Award and
  Dr SS Bhatnagar Award by CSIR
- **Fellow of FNASc, FNAAS, and FINSA**
- **Mentored Dr Vidyabhusnam and Dr BS Rana who succeeded him**
- **Aimed for Green Revolution in drylands – By making Grey Areas Green**

Dr Rao's Contributions

- His deputation to Nebraska University for a year helped to work on early dwarf sorghum hybrids. Also got access to dwarf lines including IS 3924 and milo cytoplasm
- First sorghum hybrid 'CSH-1' in 1964 & variety 'Swarna" in 1968
- Nine hybrids (CSH-1 to CSH-9) and 8 varieties (CSV-1 to CSV-8R) with higher productivity (4-5 t/ha), pest/disease resistance and better grain quality
- CSH-9 hybrid still cultivated (around 15 % area)
- His hybrids led to vibrant seed industry - both public and private

My association with him

While working as Forage Breeder at HAU, Dr Rao delegated coordination responsibility for forage sorghum

Working with him was a real learning experience

SSG 59-3 was released as first multicut forage sorghum variety

Encouraged me to write a book on Forage Sorghum

Received ICAR Rafi Ahmad Kidwai Award (1983) and Team Research Award (1984)

Era of Green Revolution

Food Production: 50 mt (1947) to over 309.0 mt (2020-21)

Impact : Household food security

Drylands (48%) facing frequent droughts were byepassed
The concern for household nutrition security continues
The need for second green revolution is evident
Consequences:

- Natural resource degradation (land, water, biodiversity)
- Remained confined to irrigated areas

Neglect of Nutri-Millets

Glamour for Rice, Wheat and Maize as food crops

Preference for diversification and higher income

Area declined by 10 m ha in Sorghum and 5 m ha in Pearl Millet

Yet area retained for Rabi Sorghum in Maharashtra and Pearl Millet in Rajasthan

Thanks to hybrid technology, both production and productivity increased

Covid 19 Pandemic

Bengal Famine of 1943 – Between 2 to 3 million people died of hunger but not due to any disease

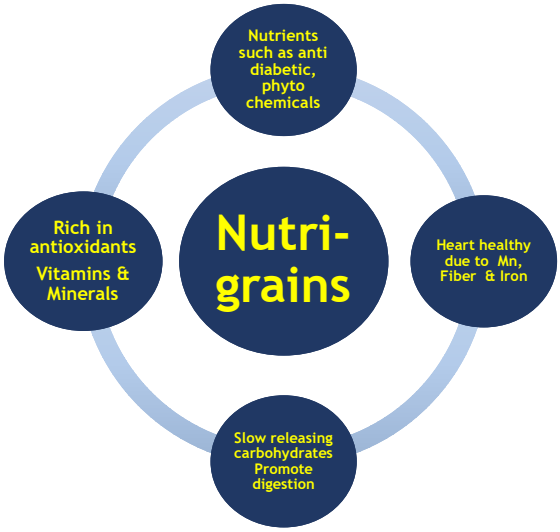
Covid has drawn global attention towards Food, Nutrition and Environmental Security

Also on food for good health and immunity with greater focus on local food systems

UN WFP – 957 million people across 93 countries do not have enough to eat

UN Food Systems Summit – Decade of Action for safe, accessible, sustainable and equitable food systems

Why Millets are Nutri-grains



High Fibre

Low Gluten

Low Fat

No Cholesterol

Millets : Comparison with other cereals

Millets	Starch (%)	Protein (%)	Fat (%)	Total dietary Fibre (%)
Sorghum	70.22	11.2	2.32	9.23
Pearl Millet	65.76	12.3	6.78	10.21
Finger Millet	59.68	9.8	3.83	10.5
Foxtail Millet	57.02	12.3	2.23	6.9
Little Millet	57.48	10.2	2.39	4.1
Barnyard Millet	57.1	9.4	3.31	2.9
Proso Millet	59.02	8.4	2.08	6.1
Kodo Millet	59.33	7.3	1.41	13.8
Rice	78.28	7.9	0.5	2.86
Wheat	64.26	11.8	1.5	11.2
Maize	74.42	9.32	2.39	8.2

Second Green Revolution

- Now not for household food but nutrition security
- To make Grey areas Green : Drylands (48 %)
- Has to be a Twin Pillar approach:
  around scaling hybrid technology
  and conservation agriculture

Global Scenario

Millets area and production (2019)

Regions	Area (lakh ha)	Production (lakh ton)
Africa	488.9	423.1
Americas	53.2	192.5
Asia	161.7	214.8
Europe	7.7	19.9
Australia & New Zealand	5.9	12.0
India	138.2	172. 5
WORLD	**717.2**	**862.6**

- **India produces 80% of Asia & 20% of Global production)**
- **Global average yield: 1229 kg/ha India:1239 kg/ha**

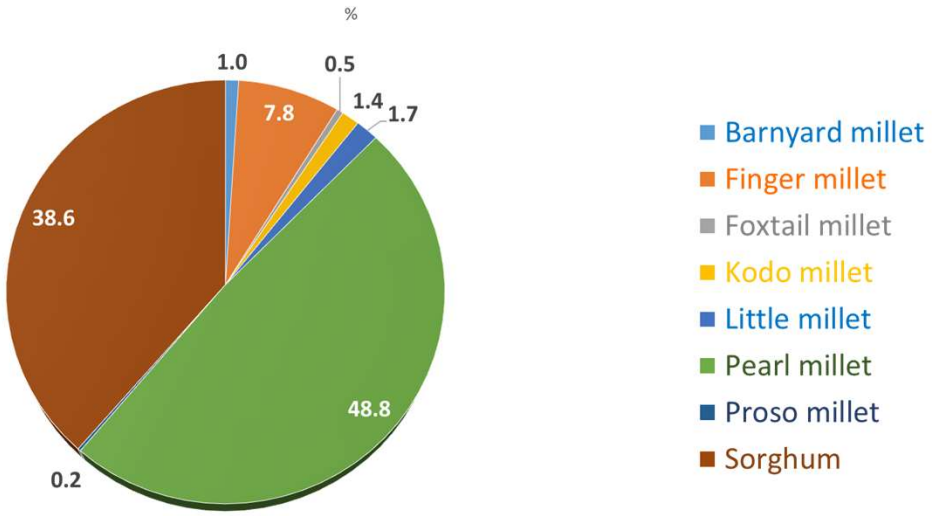
Source: FAO Stat 2021

India vs. Global Millets Production

Crop	Area (000 ha)	Production (000 tons)	Yield (kg/ha)	Per cent of world production	World Production rank
Barnyard millet	146.0	151.0	1034	99.9	1
Finger millet	1138.3	1822.0	1601	53.3	1
Foxtail millet	72.6	50.2	691	2.2	3
Kodo millet	200	84.2	419	100	1
Little millet	255.5	119.9	469	100	1
Pearl millet	7129	10280	1442	44.5	1
Proso millet	31	20.0	645	1.4	9
Sorghum	5650	4410	781	6.9	6
Total millets	**14622.4**	**12531.7**	**857**		

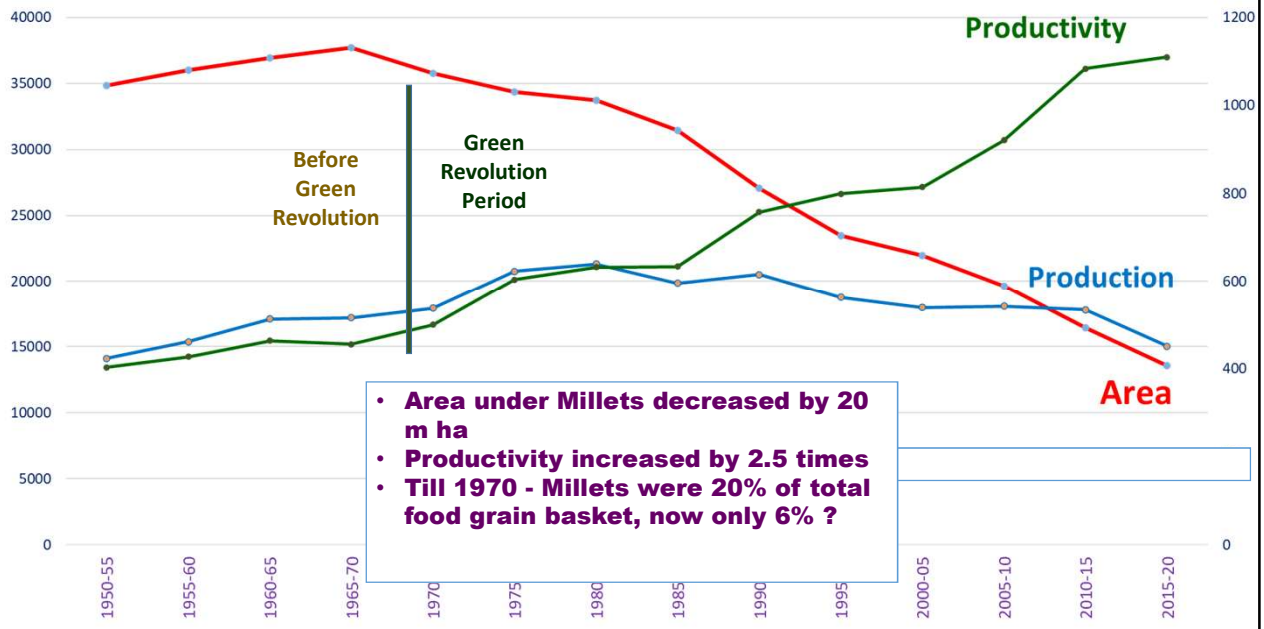
Source: IIMR estimates based on FAO/DES-GOI data

Area under millets in India



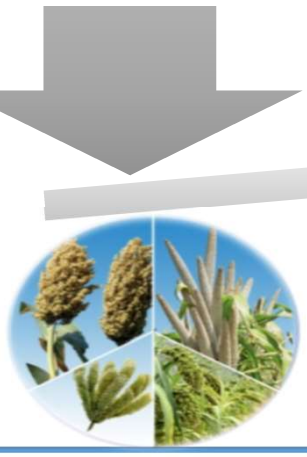
Source: Estimates based on data from Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Government of India.

INDIA : AREA, PRODUCTION & YIELD OF MILLETS



- **Area under Millets decreased by 20 m ha**
- **Productivity increased by 2.5 times**
- **Till 1970 - Millets were 20% of total food grain basket, now only 6% ?**

AREA DECLINE HAS BEEN COMPENSATED BY PRODUCTIVITY GAIN



MILLETS

Millets Area down

Millets Production Up

Millets Productivity Up

Top Hybrids Seed Production*

Sorghum				Pearl millet			
Grain sorghum		Fodder sorghum		Grain pearl millet		Fodder pearl millet	
Hybrid	Developed by	Hybrid	Developed by	Hybrid	Developed by	Hybrid	Developed by
CSH 14	*Public sector (15%)*	CSH 24MF (20%)	*Public sector*	86M90 (25%)	*Corteva*	Nutrifeed (30%)	*Advanta-UPL*
CSH 9	*Public sector (12%)*	SSG 898 (15%)	*Agrinova*	PROAGRO 9001 (20%)	*Bayer*		
CSH 16	*Public sector (15%)*	Sugar graze (15%)	*Advanta-UPL*	KAVERI SUPERBOSS (15%)	*Kaveri seeds*		
JKSH 22	*JK Agrigenetics (20%)*	Megasweet (10%)	*Advanta-UPL*	86M38 (15%)	*Corteva*		
MLSH 296	*Crystal Crop (15%)*	CSH 36F (Dairy Green) (15%)	*Crystan Crop*	DHANYA (MP 7933) (15%)	*Metahelix*		
HTJH 3201	*(23%) Hitech seeds*	Others (25%)		HHB 67 improved (10%)	*Public sector*		

*Estimates based on feedback from Seed Industry

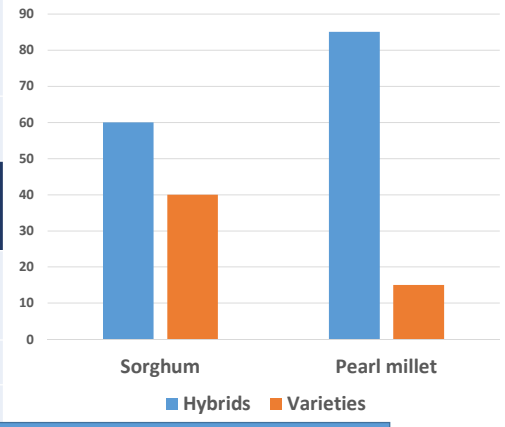
Comparison of Maldandi with Rabi Hybrids

Cultivar	Name	Grain yield (q/ha)	Stover yield (q/ha)
Variety	M 35-1	19	55
Hybrid	CSH 13R	31	56
Hybrid	CSH 39R	27	69

Yet Maldandi is most popular?

Need to Increase Area Under Hybrids

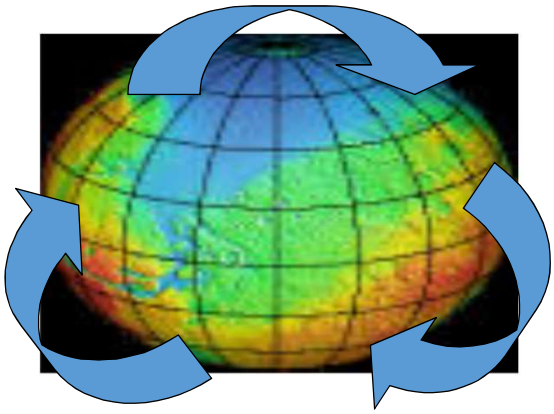
	Hybrids	Varieties
Sorghum	60%	40%
Pearl millet	85%	15%



Seed sector need to play a major role
System of Tender be stopped by State Governments
Building PPP through exclusive licensing & ABS

Way Forward

Think Globally



Act Locally

Seven Action Points

- **Increased production & productivity**
- **Nutrition & health** - Public Awareness
- **Value-addition – Processing and Value Addition**
- **Entrepreneurship / Startup / FPOs**
- **Higher income** – Branding, Labelling, Sale
- **International collaboration – ICRISAT & ARIs**
- **Policy support -** MSP linked to procurement, incentives

Action Needed

- Greater use of genetic resources
- Improving productivity and nutritional quality
- Higher coverage under hybrids
- Emphasis on conservation agriculture
- Promoting value chain

Millets Germplasm - National Genebank

CROP NAME	NO. OF ACCESSIONS	GENETIC STOCK	RELEASED VARIETY
Pearl Millet	8685	61	153
Sorghum	25527	175	203
Small Millets			
Barnyard Millet	1977	5	12
Common Millet Proso Millet	1033	0	6
Foxtail Millet	4695	4	36
Kodo Millet	2381	0	15
Little Millet	2143	2	61
Finger Millet	11478	25	166
Browntop millet	38	-	-
Grand Total	**57957**	**272**	**652**

Source : Dr Veena Gupta

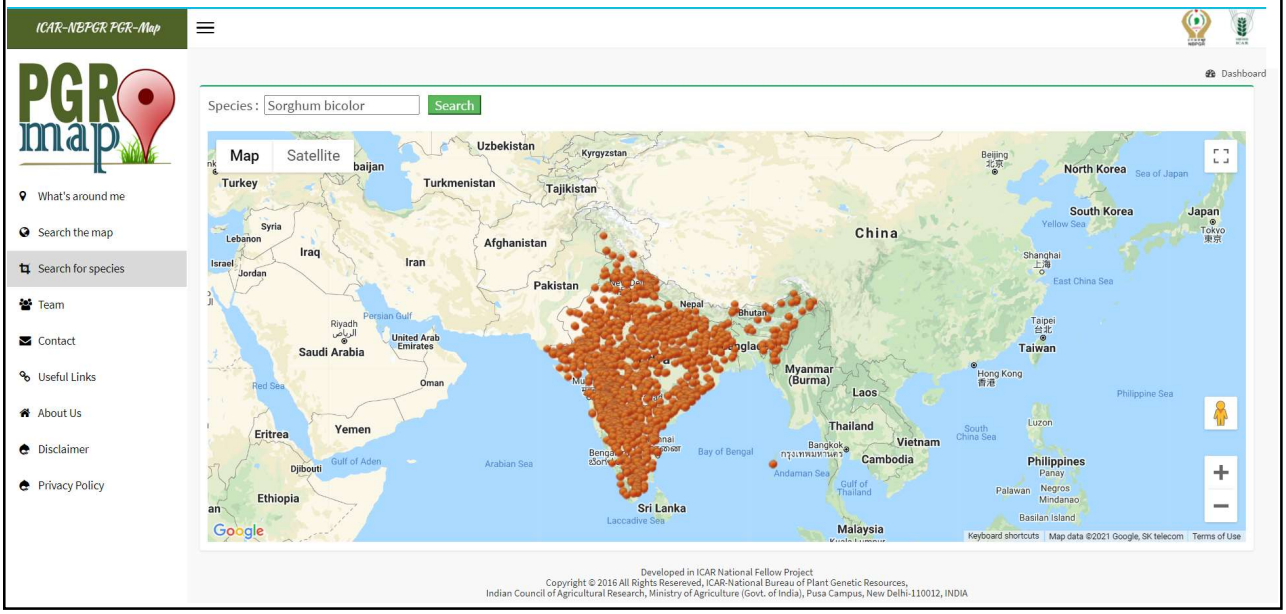
Rajendra S. Paroda Genebank - ICRISAT

- Sorghum and millets collection : **78539 accessions**
- Entire collection conserved at ICRISAT genebank : **128979 accessions**

Crop	Cultivated	Wild	Total
Sorghum	41891	461	42352
Pearl millet	23574	816	24390
Finger millet	7314	205	7519
Foxtail millet	1488	54	1542
Proso millet	849		849
Little millet	473		473
Kodo millet	665		665
Barnyard millet	749		749
Total	**77003**	**1536**	**78539**

As on Aug 2021

Millets Germplasm Collection Sites in India



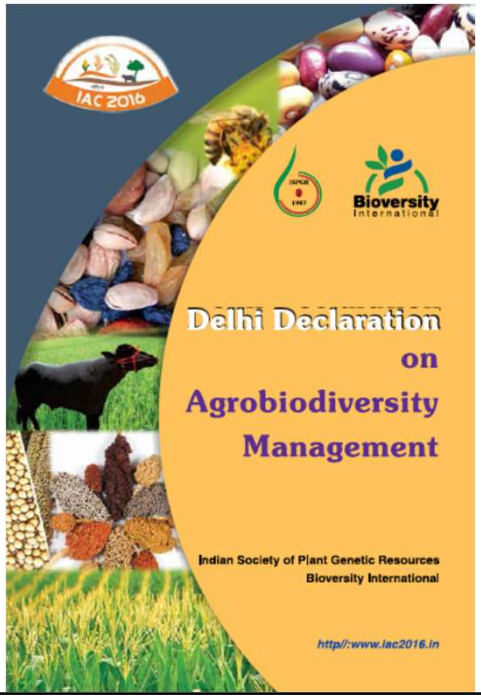
Germplasm Lines Registered (1996-2021)

Crop name	No. of accession
Barnyard millet	2
Finger millet	8
Foxtail Millet	2
Pearl millet	20
Sorghum	69
Grand Total	**101**

Traits	No. of accession
Abiotic	3
Agronomic	5
Biotic	32
Breeding value	44
Quality	17
Grand Total	**101**

Sorghum
IC0415833; INGR21041

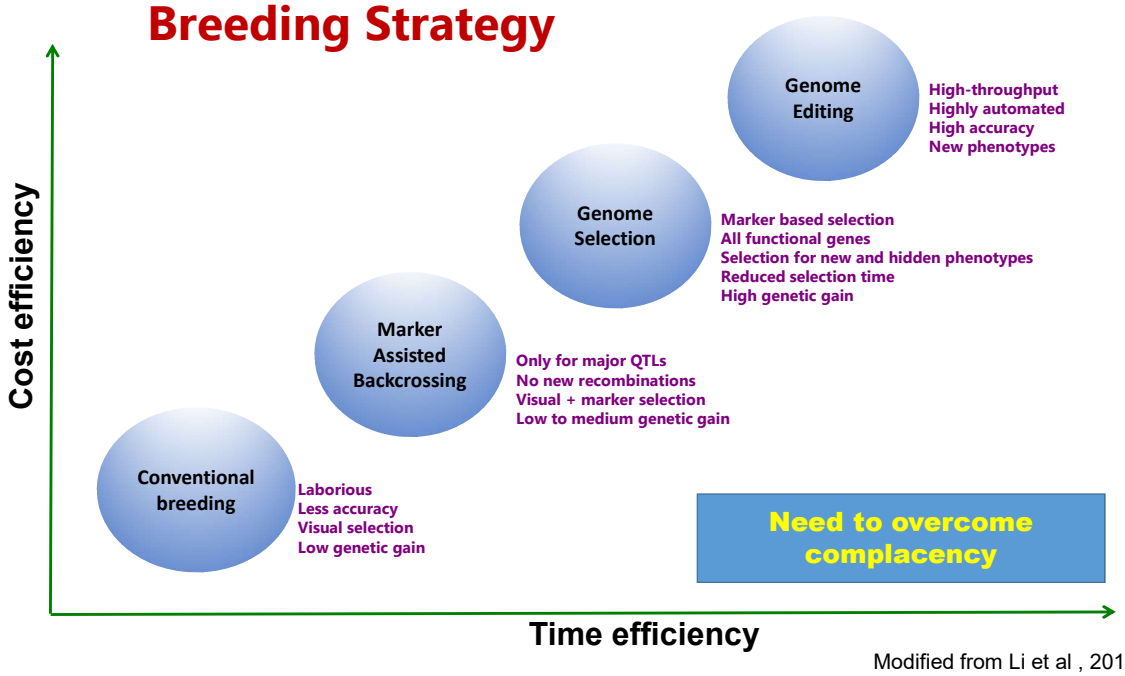
Pearl millet
IC0614156; INGR160014



1st International Agrobiodiversity Congress

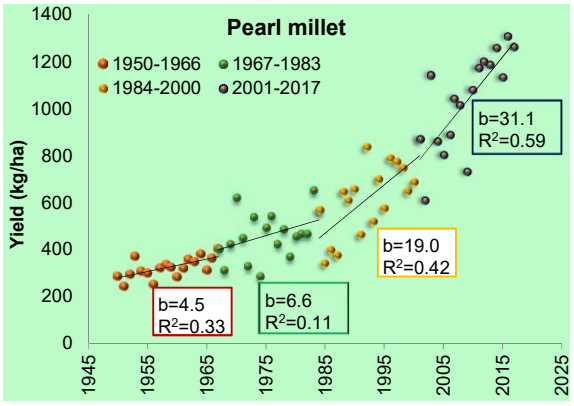
Greater emphasis on use of wild relatives and diversified germplasm in crop breeding

Breeding Strategy



Modified from Li et al , 2018

Productivity Gain (kg/ha/yr)



Source: Yadav O.P., Singh D.V., Dhillon B.S. and Mohapatra T. 2019. **Current Scien**ce 116: 1805-1808.

Source : OP Yadav

Biofortified Hybrids

AHB 1200
High Iron = 77 ppm
Zinc = 39ppm

HHB 299
High Iron = 73 ppm
Zinc = 41ppm

HHB 311
High Iron = 83 ppm
Zinc = 39 ppm

Source : Dr. C. Tara Satyavathi , 2019

Value addition- urgently needed

Food industry

- **Hybrids/varieties with high semolina recovery & high amylose/amylopectin ratio**

Feed industry

- **High protein digestibility; Low phytates**

Ethanol industry

- **High starch; High ethanol fermentation efficiency**

Millet Recipes

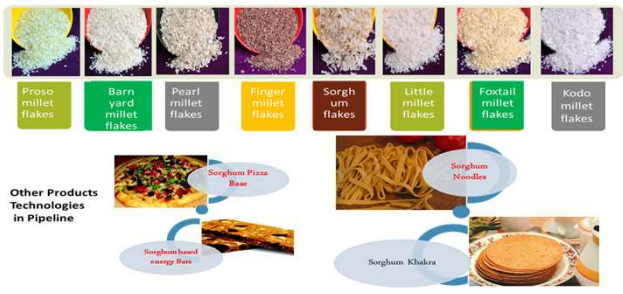
Developed **85 millet based recipes** that comes under different categories like breakfast, lunch, sweets and savories to include in our daily diet.

Packaging & Labelling

eatrite
Eat Smart - Stay Healthy

Other Value added Millet Technologies – Offered for technology licensing

All Millet Flakes



Other Products Technologies in Pipeline

Partnership with ICRISAT

Critical for making Grey Areas Green

- Enhanced germplasm use through joint evaluation,

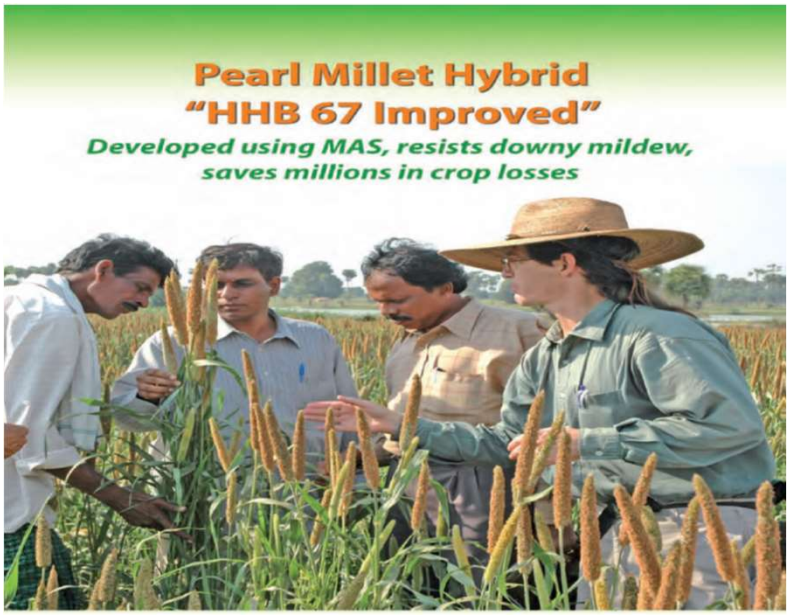
Phenotyping and accelerated pre-breeding

- Targeted efforts for genomics, genome editing and biofortification

- Basic work on drought tolerance and biotic stresses

- Strengthening work on heterotic gene pools and hybrid breeding

- Natural resource management - CA



HHB 67 Improved 2 : Through genomics-assisted breeding for rainfed ecology

- HHB 67 Improved is an immensely popular hybrid, cultivated in 850,000 ha (~10% of total area), first molecular breeding product of India
- Yearly net additional benefits to the farming community in Haryana alone reached >US$ 13.5 million
- Seed production of HHB 67 Improved gives a net annual income of >US$ 6.4 million to the smallholder seed producers in Telangana, Andhra Pradesh and Gujarat
- Every year generates at least 900,000 person days of employment (45% for women)
- The hybrid started becoming susceptible to DM threatening livelihood of millions of people in Rajasthan, Haryana and Gujarat
- ICRISAT collaborated with CCSHAU and AICRP-PM to improve the DM resistance levels
- Moved three DMR QTLs from three chromosomes, LG 3, 4 and 6
- The new hybrid christened HHB 67 Improved 2 recorded following improvements over HHB 67 Improved:
  - 59% improvement in downy mildew resistance in disease sick plots of Rajasthan, Haryana and Gujarat
  - 92% increase in downy mildew resistance against 14 representative downy mildew pathotype-isolates from A1 and A zones in controlled (greenhouse) conditions
  - 16% (281 kg/ha) more grain yield
  - 23% (965 kg/ha) more dry fodder yield
- Matures a day earlier than HHB 67 Improved
- Released for the dry zones of Rajasthan, Haryana and Gujarat
- Identified as one of the cultivars to be dedicated to the Nation by the Hon'ble PM of India

ICRISAT

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Center of Excellence in Genomics & Systems Biology

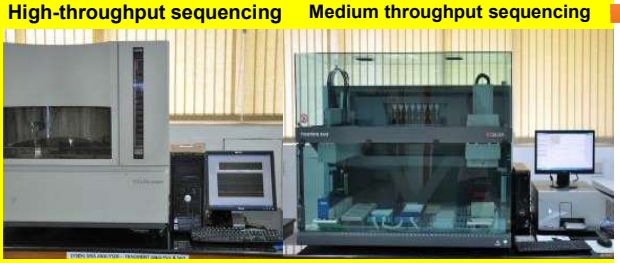
Striving towards efficient breeding and research for better crop performance and human health

https://cegsb.icrisat.org/

HOME | APPLIED GENOMICS | SYSTEMS BIOLOGY | SERVICES | CAPACITY BUILDING | OPEN ACCESS | RESOURCES | NEWS | CONTACTS

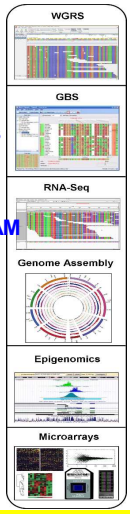
Genotyping and sequencing platforms

High-throughput sequencing | Medium throughput sequencing



SSR genotyping | SNP genotyping

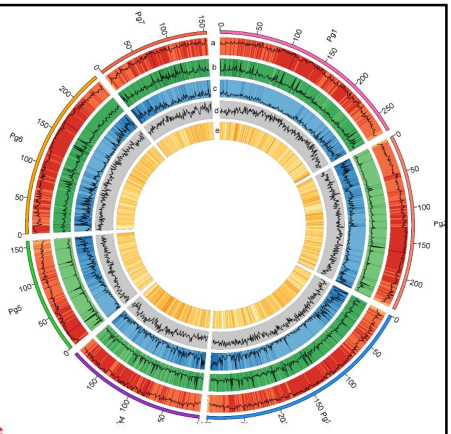
- 600 cores
- 830 TB storage
- 7.5 TB RAM



High Performance Computational Genome Analysis facility

Pearl millet genome sequence: A consortium led by ICRISAT

- ~1.79 Gb genome of Tift 23D2B1-P1-P5 reference genotype was assembled, 38,579 genes.
- 994 germplasm lines re-sequenced
- Heterotic groups defined based on resequencing data
- A resource for improving heat and drought tolerance



nature biotechnology
OPEN

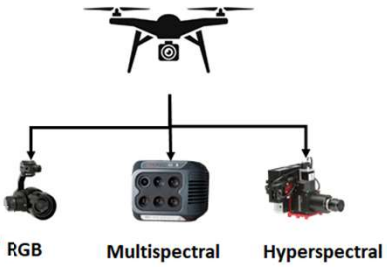
Source : R. Varshney

Pearl millet genome sequence provides a resource to improve agronomic traits in arid environments

Rajeev K Varshney[1,33], Chengcheng Shi[2,33], Mahendar Thudi[1], Cedric Mariac[3], Jason Wallace[4], Peng Qi[4], He Zhang[2], Yusheng Zhao[5], Xiyin Wang[4], Abhishek Rathore[1], Rakesh K Srivastava[1], Annapurna Chitikineni[1], Guangyi Fan[2], Prasad Bajaj[1], Somashekhar Punnuri[6], S K Gupta[1], Hao Wang[7], Yong Jiang[8], Marie Couderc[3], Mohan A V S K Katta[1], Dev R Paudel[9], K D Mungra[9], Wenbin Chen[2], Karen R Harris-Shultz[10], Vanika Garg[1], Neetin Desai[11,12], Dadakhalandar Doddamani[1], Ndjido Ardo Kane[13], Joann A Conner[14], Arindam Ghatak[11,15], Palak Chaturvedi[11], Sabarinath Subramaniam[16,17], Om Parkash Yadav[18], Cécile Berthouly-Salazar[3,19], Falalou Hamidou[20,21], Jianping Wang[8], Xinming Liang[2], Jérémy Clotault[3,22], Hari D Upadhyaya[1], Philippe Cubry[3], Bénédicte Rhoné[3,23], Mame Codou Gueye[13], Ramanjulu Sunkar[24], Christian Dupuy[25], Francesca Sparvoli[26], Shifeng Cheng[2], R S Mahala[27], Bharat Singh[6], Rattan S Yadav[28], Eric Lyons[29], Swapan K Datta[29], C Tom Hash[30], Katrien M Devos[4], Edward Buckler[7,30], Jeffrey L Bennetzen[4], Andrew H Paterson[4], Peggy Ozias-Akins[14], Stefania Grando[1], Jun Wang[2], Trilochan Mohapatra[31], Wolfram Weckwerth[11,32], Jochen C Reif[9], Xin Liu[2,33], Yves Vigouroux[3,22] & Xun Xu[2,33,34]

Phenotyping

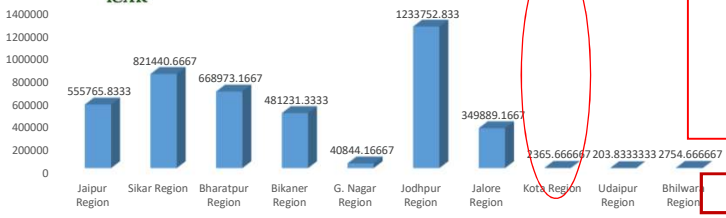
https://gems.icrisat.org/uav-phenotyping/



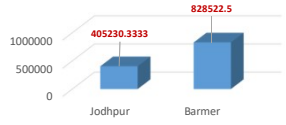
Lysimetry Complex for drought tolerance at ICRISAT

Lysimetry Complex @ ICRISAT

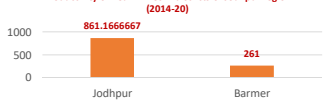
Bridging Yield Gaps Eco-regionwise



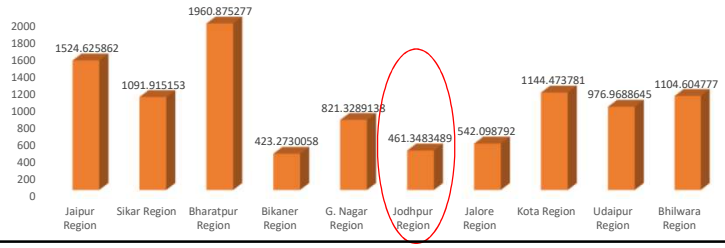
Area of Pearl millet in districts of Jodhpur region (2014-20)



Productivity of Pearl millet in districts of Jodhpur region (2014-20)



Productivity of Pearl millet in different regions of Rajasthan (2014-20)



OPPORTUNITIES

- **2018 was "National Year of Millets"**
- **2023 to be an "International Year of Millets"**
- **National Mission on Millets (nutri-cereals)-**
  Initiated in 2018 for 5 years (outlay $21 million)
- **MSP : Sorghum hybrid Rs 2738, Maldandi Rs 2758;**
  Bajra Rs 2250; Paddy Rs 1960; Wheat Rs 1975; Maize Rs 1870
- Like for Quinoa (2013), public awareness needed
- India – Will be a True Happening Place

Policy Support Needed

- MSP to be linked to procurement by States
- Inclusion of millets in Mid-day-Meal scheme
- Including millets in PDS, ICDS, ODOFP programs
- Premium needed on biofortified varieties
- Incentives to FPOs in millet growing districts
- GST exemption to youth on value added products

Future Strategy

- Doubling R&D Allocation on Millets
- A Consortium on Hybrid Millets
- Strong Public-Private Partnership
- Promoting South-South Collaboration
- To apply GI for Maldandi (ex. Basmati Rice)
- A Road Map on Millets for 2030

Millets to Make Grey Areas Green

Finally, Millets for Health & Prosperity

THANK YOU