Conserving Biodiversity at ICRISAT

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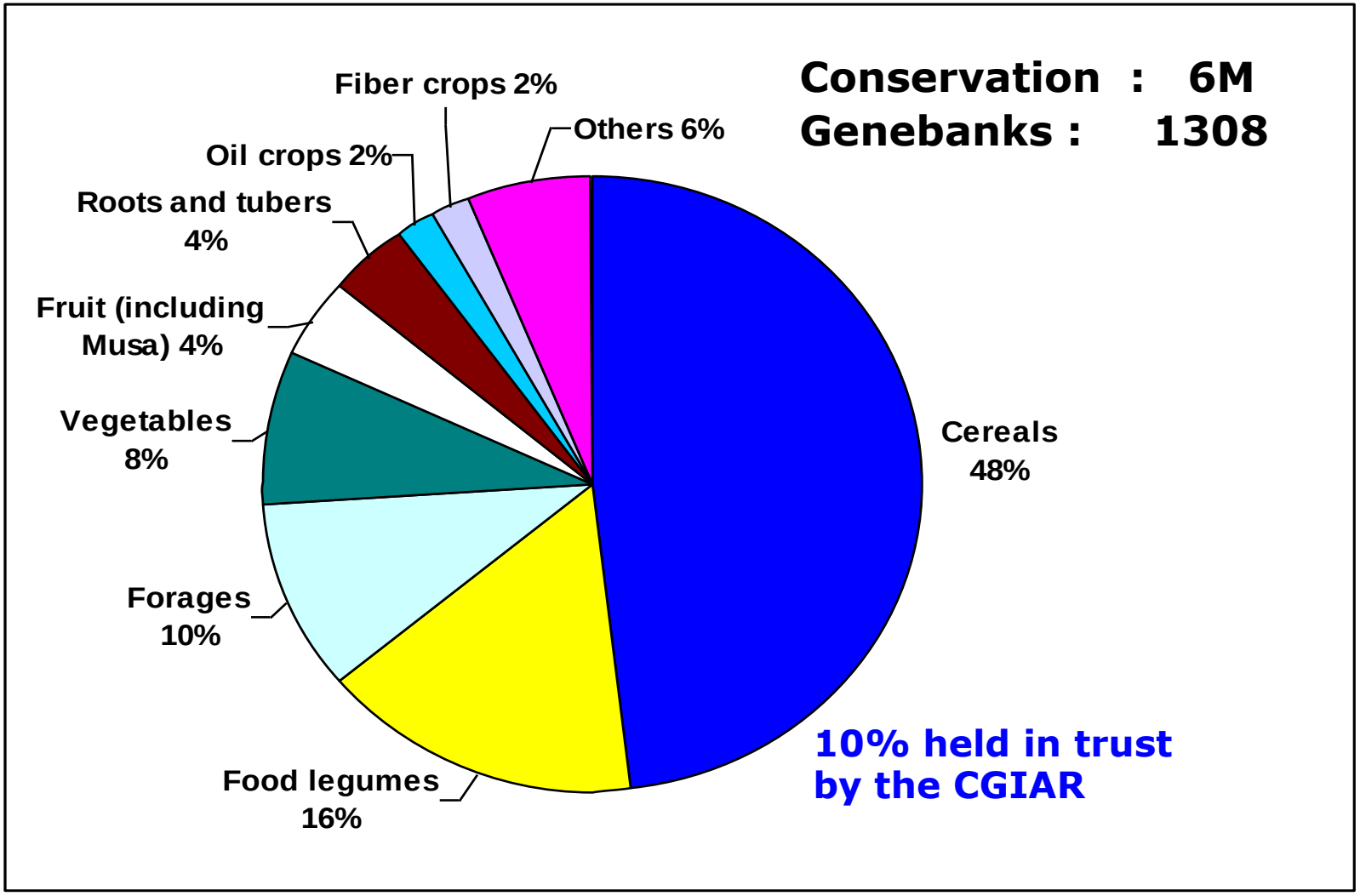
Need for biodiversity

- Plant genetic resources (PGR) are finite and vulnerable
- PGR are the biological basis of world food security and support livelihoods
- Erosion of PGR severely threatens world food security
- This realization led to the Convention on Biological Diversity in 1992

Global germplasm accessions



Source: Food and Agriculture Organization of the United Nations. 1998.

ICRISAT mandate crops

Important to the diets and livelihoods of the poorest of the poor

Sorghum

Millet

Groundnut

Chickpea

Pigeonpea

Small millets germplasm at ICRISAT

Finger millet

Foxtail millet

Proso millet

Little millet

Kodo millet

Barnyard millet

Germplasm collection/assembly at ICRISAT

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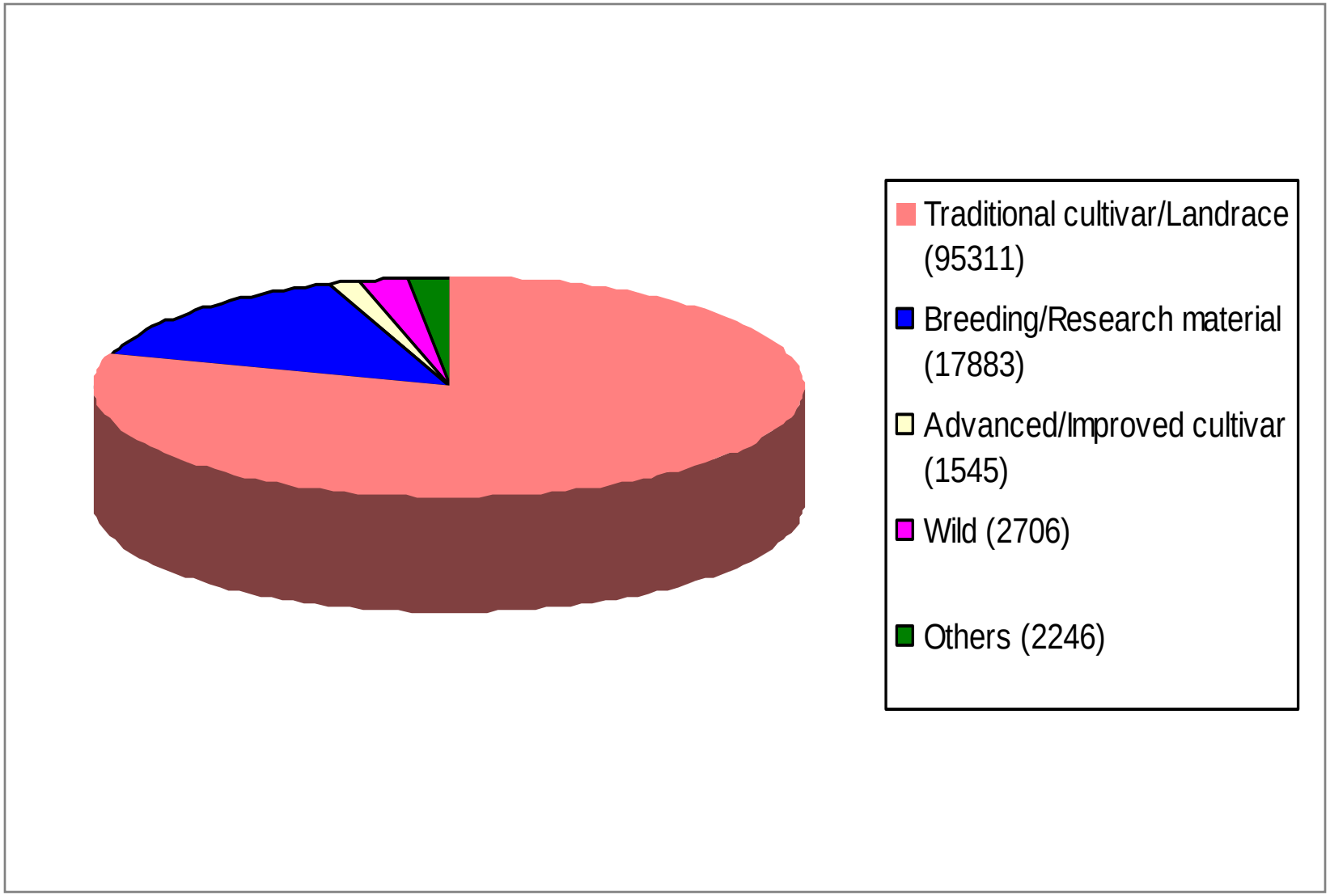
- 119,691 accessions assembled/collected from 144 countries
- 94,863 accessions from 56 SAT countries
- 33,194 samples from 213 collection missions in 62 countries
- 2706 accessions of wild relatives representing 16 genera and 132 species
- 113,830 accessions (95.1%) in-trust with FAO
- 113,401 accessions (95.2%) characterized for morpho-agronomic traits

Biological status of germplasm - ICRISAT genebank



Germplasm distribution at ICRISAT

- ICRISAT under Agreement with Treaty (ITPGRFA) for sharing germplasm under Multi Lateral System (MLS)
- 704,317 samples distributed in 144 countries
- 569,202 samples in 52 SAT countries
- 66 accessions released as popular cultivars in 44 countries contributing to food security

Germplasm restoration by ICRISAT

ICRISAT genebank has restored several thousand accessions of germplasm to country of origin upon request

- Botswana (362 sorghum)
- Cameroon (1827 sorghum and 922 pearl millet)
- Ethiopia (1723 sorghum and 931 chickpea)
- India (44,701 accessions of 5 mandate and six small millets)
- Kenya (838 sorghum and 332 pigeonpea)
- Nigeria (1436 sorghum)
- Somalia (445 sorghum)
- Sri Lanka (71 pigeonpea)
- Sudan (977 sorghum and 594 pearl millet)

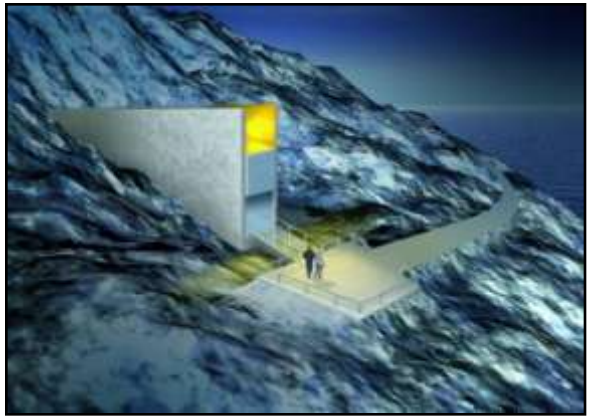
Germplasm conservation at ICRISAT

- Medium-term storage (20-25 years) at 4^0C and 30% RH - Seed viability >85%
- Long-term storage (>50 years) at -20^0C with 3-7% seed moisture - Seed viability >90%
- Maintenance as live plants in special facilities and botanic garden

Safety back-up of ICRISAT germplasm

Safety back up (-20^{0}C with 3-7% seed moisture) - Seed viability >90%

- Chickpea at ICARDA (Syria)
- Millets and groundnut at Niamey (Niger)
- All crops at Svalbard Global Seed Vault (Norway)



ICRISAT regional genebanks

- Niamey, Niger – 33,995 accessions of sorghum, pearl millet, pigeonpea, groundnut and finger millet

- Nairobi, Kenya – 5,910 accessions of sorghum, pearl millet, chickpea, pigeonpea, groundnut and finger millet

- Bulawayo, Zimbabwe – 7,831 accessions of sorghum and pearl millet

Cost-effective strategies for managing the collections at ICRISAT

- Groundnut seed over pod storage – without significantly compromising storage longevity
- Ultra-dry storage - groundnut, sorghum and pearl millet seed maintained higher levels of viability under ambient and higher temperatures thereby avoiding refrigeration
- Pigeonpea regeneration – insect proof caging superior over covering with muslin cloth bags in terms of seed yield, seed quality and crop management

Reasons for under utilization of germplasm in crop improvement

- Large size of collections
- Lack of information on accessions, particularly for traits of economic importance
- Inadequate linkages between genebanks and users
- Use of limited diversity in working collection

Overcoming low use of germplasm in crop improvement

- Core collection 10% entire collection - Sir Otto Frankel
- Due to reduced size core collection can be evaluated extensively identifying genetically diverse germplasm for use by breeders
- Mini core ~10% of core or ~1% of entire collection (Upadhyaya and Ortiz 2001)

Core, mini core and composite collections and germplasm reference sets at ICRISAT

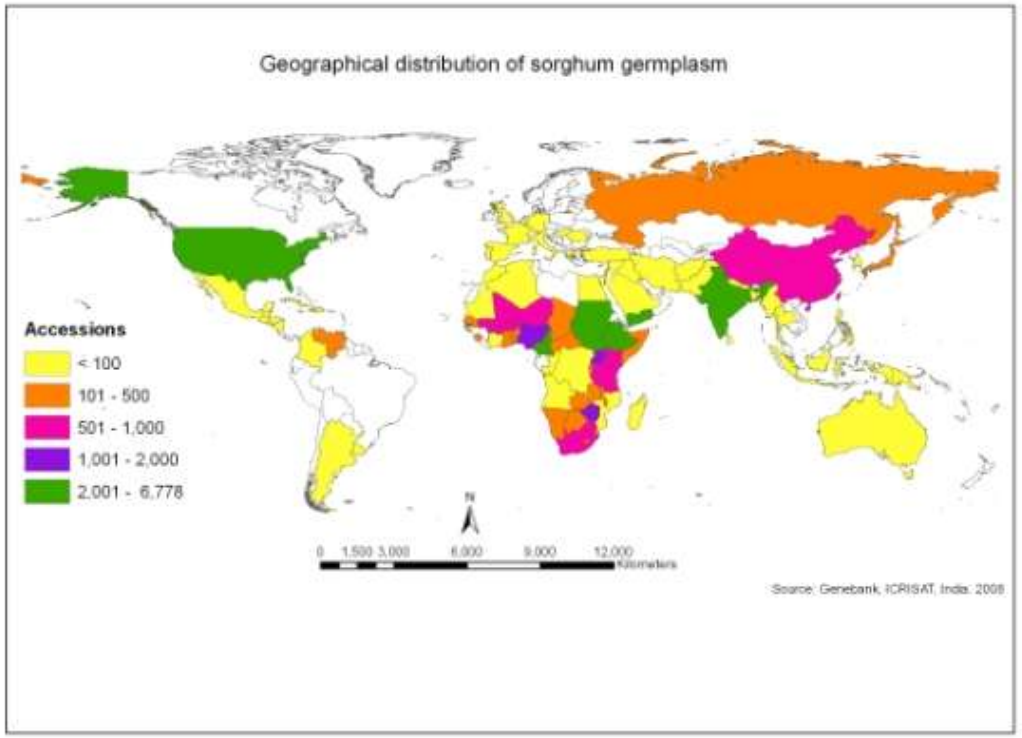
Crop	Number of accessions					
	Entire collection	Used in core development	Core collection	Mini core collection	Composite collection	Reference set
Sorghum	37,904	22,474	2,247	242	3,384	384
Pearl millet	21,594	20,844	2,094	238	1,021	300
Chickpea	20,140	16,991	1,956	211	3,000	300
Pigeonpea	13,632	12,153	1,290	146	1,000	300
Groundnut	15,419	14,310	1,704	184	1,000	300
Finger millet	5,949	5,940	622	80	1,000	300
Foxtail millet	1,535	1,474	155	-	500	200

Sorghum biodiversity at ICRISAT

- Sorghum [*Sorghum bicolor* (L.) Moench] is fifth most important cereal in the world
- Grown mainly in the semi-arid areas of tropics and subtropics
- Annual global production 64.6 million t from 43.8 million ha.

Sorghum germplasm assembly at ICRISAT

- Landraces - 32,518
- Breeding material - 4,862
- Advanced cultivars - 105
- Wild - 458



Maintenance of sorghum germplasm at ICRISAT

- Sorghum germplasm is maintained by using selfing and bulking techniques to avoid cross pollination
- Male sterile lines are maintained by hand pollination

Characterization and evaluation in sorghum at ICRISAT

- Sorghum germplasm is characterized for important morpho agronomic characters
- Known the relative worth of each accession for use by scientists
- Identified several sources of resistance to aboitic and biotic stresses
- Developed core, mini core, composite collections and reference set
- Evaluated germplasm sets at different locations

Classification of sorghum germplasm

Sorghum germplasm is classified into five basic races and ten intermediate races (Harlan and de Wet 1972.)

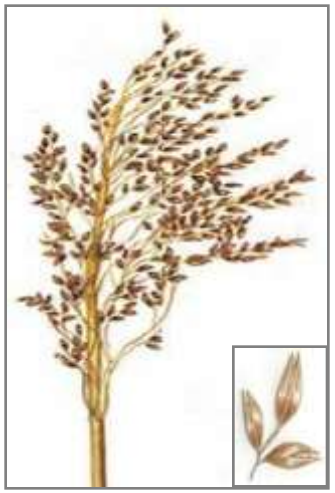
Five basic races are:

Bicolor, Guinea, Caudatum, Kafir and Durra

Ten intermediate races are:

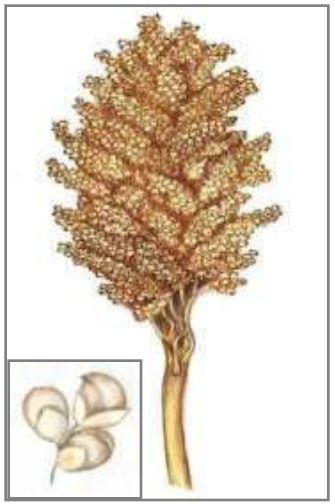
Guinea bicolor, Guinea caudatum, Guinea kafir, Guinea durra, Caudatum bicolor, Kafir bicolor, Durra bicolor, Kafir caudatum, Kafir durra, and Durra caudatum

Five basic races in sorghum



Bicolor

Guinea



Caudatum

Kafir

Durra

Zerazera sorghums

- 120 landraces originating from Ethiopia and Sudan
- These landraces has proved to be a source of useful traits such as excellent grain quality, high grain yield potential, tan plant, straw glume color and tolerance to grain weathering
- Resistance source for leaf diseases with good agronomic background
- Widely used in crop improvement programs

Wild sorghums in ICRISAT genebank

- 458 wild sorghums consists of 20 species
- Source for pests and disease resistance
- S. *dimidiatum* is resistant to shoot fly

Range of variation for important agronomic traits in sorghum at ICRISAT

Character	Min	Max	Mean	Var.
Days to flower	33.0	199.0	107.40	807.19
Plant height (cm)	50.0	655.0	337.17	10828.00
Peduncle exsertion (cm)	0.0	72.0	16.29	87.58
Head length (cm)	2.5	86.0	22.33	65.65
Head width (cm)	1.0	80.0	9.35	19.60
Grain size (mm)	0.8	6.0	2.97	0.28
100 seed weight (g)	0.2	9.4	3.02	1.00

Sorghum germplasm screened and promising sources identified

Promising lines for pest resistance

- Shoot fly - 19,833 accessions screened and 844 promising
- Stem borer - 6,776 accessions screened and 70 promising
- Midge - 10,937 accessions screened and 121 promising
- Head bug - 9,918 accessions screened and 62 promising

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Sorghum germplasm screened and promising sources identified

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Promising lines for disease resistance

- Grain mold - 8,478 accessions screened and 156 promising
- Anthracnose - 7,750 accessions screened and 76 promising
- Rust - 7,459 accessions screened and 61 promising
- Downy mildew - 16,652 accessions screened and 168 promising
- Striga (field Screening) - 7,388 accessions screened and 254 promising

Alternative uses of sorghum

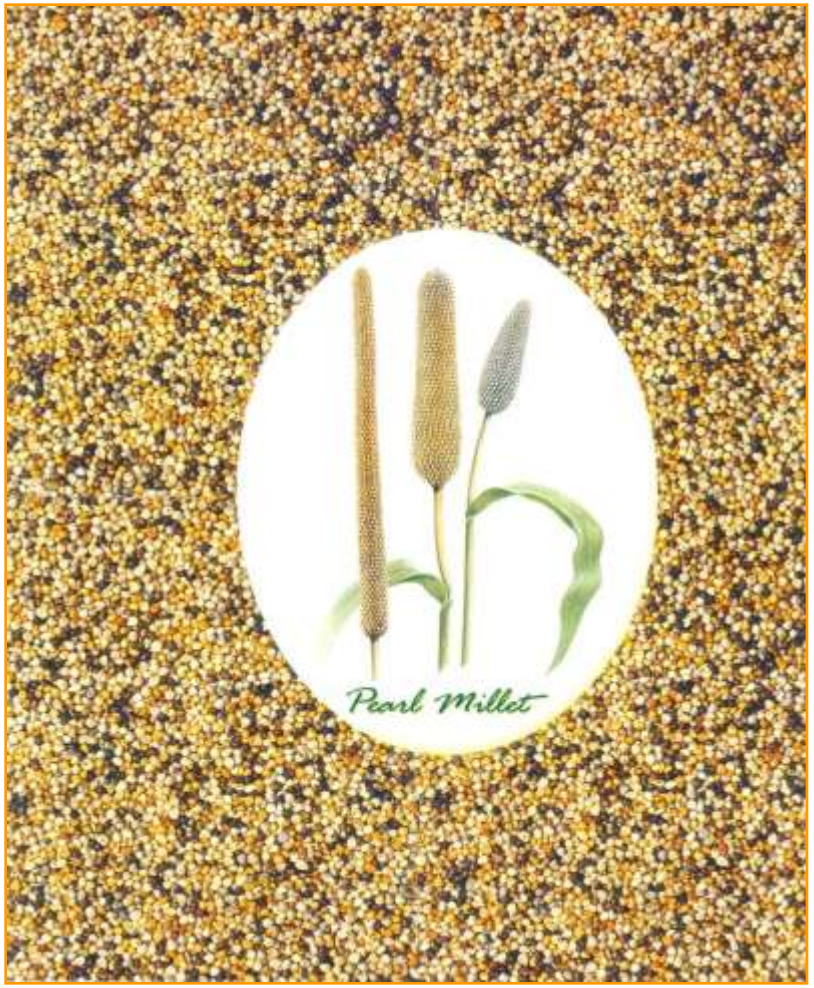
- Bread/cakes
- Cookies/biscuits
- Forage
- Feed
- Beverages (beer & malted drinks)
- Popping
- Broomcorn
- Sweet stalks for ethanol

ICRISAT sorghum germplasm released as varieties

Accession number	Country of origin	Country of release	Released name	Year of release
IS 6928	Sudan	India	Moti	1978
IS 8965	Kenya	Myanmar	Shwe-ni 1	1980
IS 2940	USA	Myanmar	Shwe-ni 2	1981
IS 302	China	Myanmar	Shwe-ni 10	1980
IS 5424	India	Myanmar	Shwe-ni 8	1980
IS 30468	Ethiopia	India	NTJ 2	1980
IS 18758	Ethiopia	Burkina Faso	E-35-1	1983
IS 4776	India	India	U P Chari-1	1983
IS 9302	South Africa	Ethiopia	ESIP 11	1980
IS 9323	South Africa	Ethiopia	ESIP 12	1984
IS 2391	South Africa	Swaziland	MRS 13	1989
IS 3693	USA	Swaziland	MRS 94	1989
IS 8571	Tanzania	Mozambique	Mamonhe	1989
IS 23520	Ethiopia	Zambia	Sima	1989
IS 9321	South Africa	Mexico	--	1990
IS 9447	South Africa	Mexico	--	1990
IS 13809	South Africa	Mexico	--	1990
IS 18758	Ethiopia	Burindi	Gambella 1107	1990
IS 9830	Sudan	Sudan	Mugawim Buda-2	1991
IS 3923	Zimbabwe	Botswana	Mahube	1994
IS 23496	Ethiopia	Tanzania	Pato	1995
IS 3541	Sudan	India	CS 3541	--
IS 3924	Nigeria	India	Swarna	--
IS 18484	India	Honduras	Tortillerio 1	1984
IS 8193	Uganda	Rwanda		2001
IS 8193	Uganda	Kenya	Kari Matama 1	2001
IS 9468	South Africa	Mexico	Marvilla No SOFO 430201092	2000
IS 13444	Zimbabwe	Sudan	Arous el Rimal	2000
IS 29415	Lesotho	Eritrea	Shiketi	2000
IS 15401	Cameroon	Mali	Soumalemba	2001
IS 21219	Kenya	Rwanda		2001
IS 25395	Kenya	Rwanda		2001
IS 33844	India	India	Parbhani Moti	2002

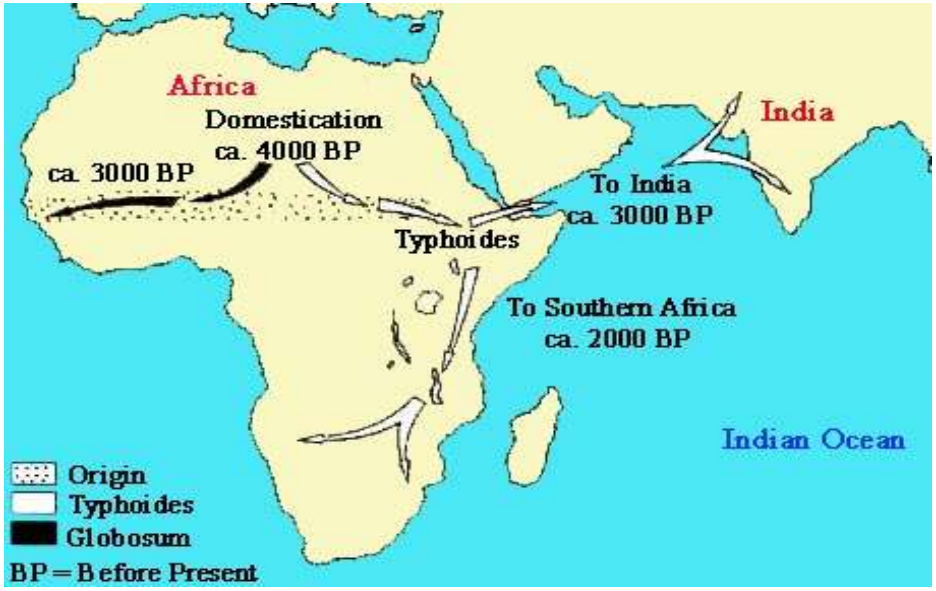
Pearl millet biodiversity at ICRISAT

- Pearl millet is the hardiest crop
- Can thrive on poor soils of dry regions in hot climates due to climate change
- Staple food for millions of people who live in the arid and semi-arid regions of Africa and Asia
- Important source of feed and forage in the Americas



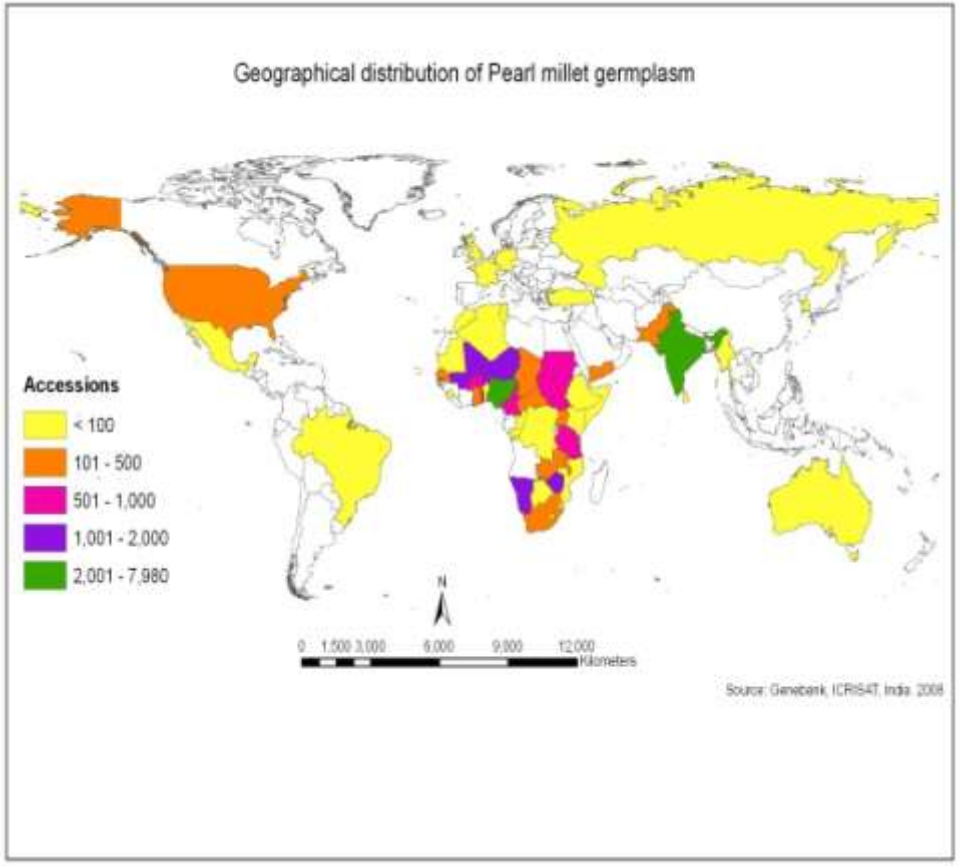
Origin and domestication of pearl millet

- Originated in a diffuse belt stretching from Senegal to western Sudan
- Domesticated 4000 years ago at its place of origin
- Reached Eastern Africa and India about 3000 years ago
- Spread to Southern Africa some 2000 years ago



Pearl millet germplasm assembled at ICRISAT genebank

- Total accessions : 21,594
- Number of countries : 50
- Cultivated : 20,844
- Wild : 750
- Introductions : 10,764
- Collections : 10,830



Pearl millet germplasm regeneration at ICRISAT

- Being a cross pollinating crop, maintaining the genetic integrity of accessions is difficult and costly
- Cluster bagging, a cost effective method developed at ICRISAT genebank is being used to control the pollination

Pearl millet characterization and utilization

To enhance the utilization of available diversity

- Enlarged collections by identifying gaps and exploration
- Characterized 98% of the collection
- Evaluated trait-specific germplasm sets in different countries
- Organized field days

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Pearl millet characterization and utilization at ICRISAT

- Developed core and mini core collections
- Developed composite collection and identified genetically most diverse reference set
- Developed trait-specific genepools to provide partially converted genotypes
- Identified several sources of resistance to abiotic and biotic stresses and useful traits

Range of variation for important agronomic traits in pearl millet

Character	Minimum	Maximum	Mean	Variance
Days to 50% flowering	33	159	72.8±0.2	569.7
Plant height (cm)	30	490	246±0.5	4427.6
Total tillers (no.)	1	35	2.7±0.0	3.1
Productive tillers (no.)	1	19	2.1±0.0	1.2
Panicle exersion (cm)	-45	29	3.7±0.1	43.3
Panicle length (cm)	5	135	28.2±0.1	112.0
Panicle thickness (mm)	8	58	24±0.0	22.7
1000-seed weight (g)	1.5	21.3	8.5±0.0	4.9

Promising pearl millet sources identified for biotic and abiotic stresses and quality traits

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Stress/Trait	Number of accessions screened	Number of promising sources identified
Cultivated		
Downy mildew	4727	54
Smut	1747	397
Ergot	2752	283
Rust	2229	332
Drought	115	7
Salinity	48	32
Sweet stalks	150	16
Yellow endosperm	137	3
High seed protein (>15%)	1270	260
High seed iron and zinc (>85; >65 ppm)	149	16
Wild		
Downy mildew	534	220

Promising pearl millet wild relatives identified for useful traits

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Species	Number of accessions	Useful traits
P. monodii	335	Progenitor, source for new cytoplasm
P. purpureum	35	Forage
P. polystachion and P. pedicellatum	88	Downy mildew resistance, high tillering
P. mezianum	4	Drought tolerance
P. flaccidum	6	Forage
P. hohenackeri	8	Thatching and rope making
P. orientale	33	Drought tolerance, soil binding and forage
P. setaceum	11	Ornamental
P. squamulatum	2	Winter hardiness, high green fodder, Apomixis
P. villosum	2	Ornamental
P. macrostachyum	1	Ornamental

ICRISAT pearl millet germplasm released as varieties

Germplasm source	Variety released	Country of release
IP 17862	MP 124	India
IP 17862	PCB 138	India
IP 17862	Okashana 1	Namibia
IP 17862	Nyankhombo	Malawi
IP 17862	ICMV 88004	India
IP 17862	Okashana 2	Namibia
IP 11381	IKMP 3	Burkina Faso
IP 11317	IKMP 5	Burkina Faso
IP 6426	Benkadi Nio	Burkina Faso, Mali
IP 17527 & IP 17531	Kangara and PMV 3	Namibia, Zimbabwe

Impact of pearl millet germplasm conserved at ICRISAT genebank

- The greatest impact is conserving the vanishing germplasm and making available for crop improvement
- *Iniadi* landrace germplasm from Togo and Ghana is the best source material for most of ICRISAT developed varieties
- Sources of resistance to biotic and abiotic stresses, leaf mutants, dwarfs, new sources of cytoplasm identified in the collection are widely used in crop improvement programs and academic studies
- Restored the pearl millet germplasm to India and Sudan

Chickpea biodiversity at ICRISAT

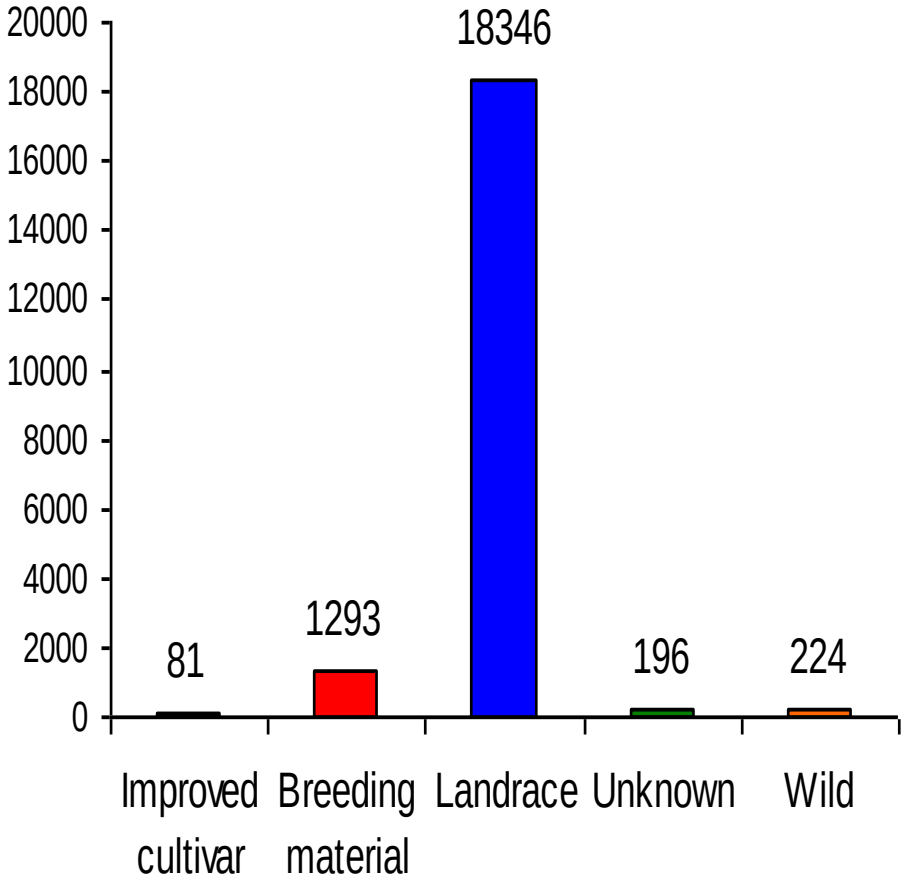
- Chickpea is the third most important food legumes grown in about 11.7 million ha
- Its seeds contain protein, fiber, calcium, potassium, phosphorus, iron, zinc and magnesium
- It is nitrogen fixing leguminous crop and grow well under limited soil moisture conditions
- Hair like structures on its stem, leaves and pods secrete acids that provide first line of defense against insect/pests infestation

Chickpea biodiversity at ICRISAT

- Important grain-legume crop producing 9.3 Mt from 11.7 m ha in 53 countries (FAO, 2007; http//faostat.fao.org)
- Low productivity (0.80 t ha^{-1})
- Grown in India on 7.63 m ha with 5.97 mt production
- Over two-thirds global production occurs in seasonally rainfed regions
- Africa and Asia contribute 93.9% to world production
- Indian subcontinent (India, Nepal, Bangladesh, Pakistan, and Myanmar) contributes 76.5% to global production
- Highest productivity in China (4.8 t ha-1) and lowest in Eritrea (0.19 t ha-1)

Chickpea germplasm at ICRISAT genebank

- Accessions: 20,140
- Countries : 60
- Cultivated : 19,916
- Wild : 224
- Collection : 4,228
- Introduction: 15,912



Chickpea characterization and evaluation at ICRISAT

- Characterized for 7 morphological,14 agronomic, protein contents, and major biotic and abiotic stresses
- Assessed phenotypic and geographical patter of diversity
- Developed core (1956 acc.), mini core (211 acc.), composite collection (3000 acc.), and reference set (300 acc.) to enhance germplasm utilization in crop improvement
- Identified trait-specific germplasm

Range and means in chickpea collection at ICRISAT

Character	Range	Mean
Plant height (cm)	14.0-105	37.7
Plant width (cm)	13.3-124	40.6
Days to flowering	31-107	62.5
Flowering Duration	13-75	34.1
Days to maturity	84-169	115.9
Pods per plant	2-251	40.4
Seeds per pod	1-3.2	1.2
Seed yield (Kg ha^{-1})	70-5130	1221.1
Seed weight (g)	3.8-65.4	16.8
Protein content (%)	8-29.6	19.5

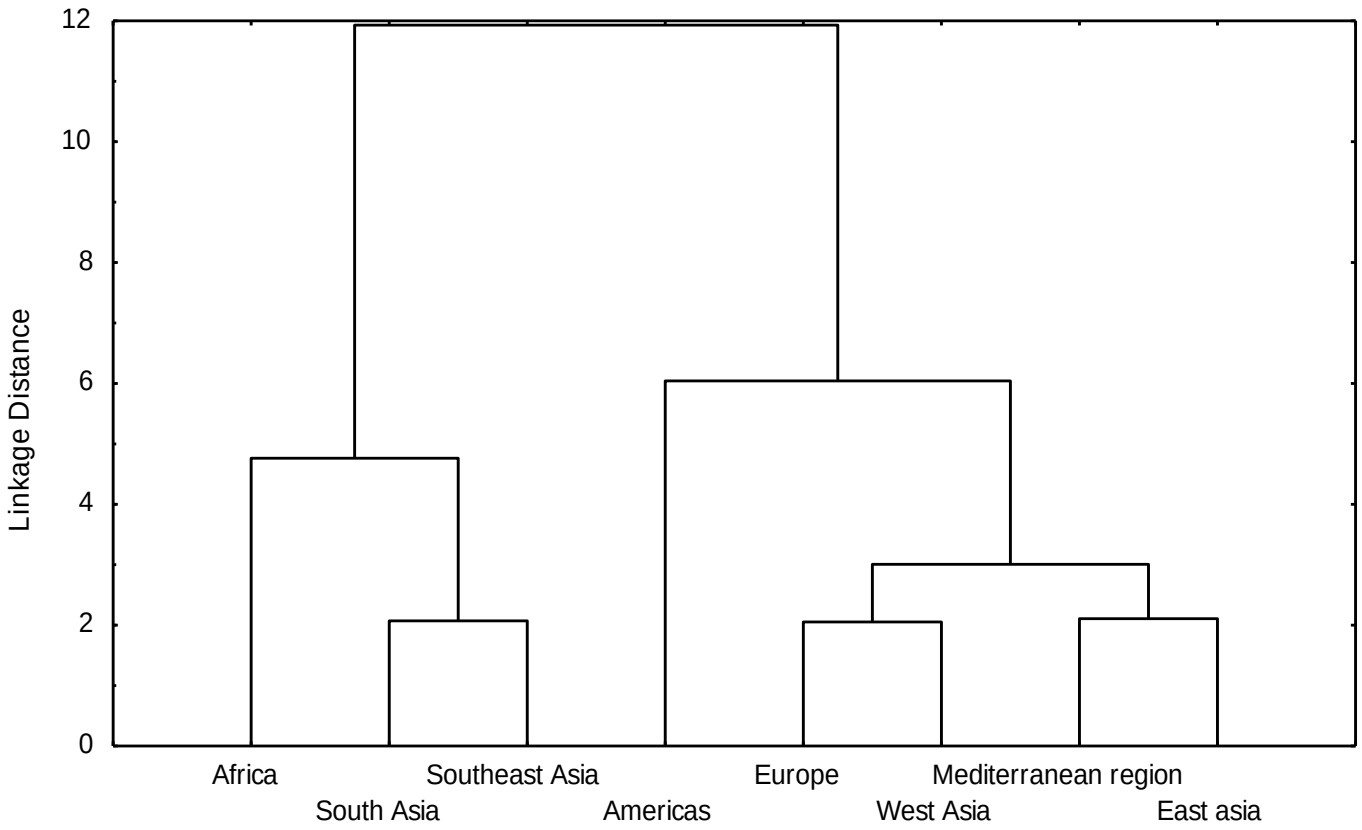
Geographical pattern of diversity in chickpea

- Geographical information available on16820 accessions, were used in diversity analysis
- 7 morphological and 13 agronomical traits, and data on reaction to wilt were used
- 25 years data (1974-1998) were used

Geographical diversity in chickpea at ICRISAT

- Significant differences for range of variation for morphological and agronomic traits
- South Asia captures maximum (96%) and Southeast Asia minimum (40%) range percentage of entire collection
- Significant differences among regions for means of all agronomic traits
- Variances for all the agronomic traits were heterogeneous

Diversity in chickpea germplasm at ICRISAT



Dendogram of eight regions of entire chickpea germplasm based on first three principal components (90.9% variation) of 13 agronomic traits

Chickpea accessions identified for major stresses at ICRISAT

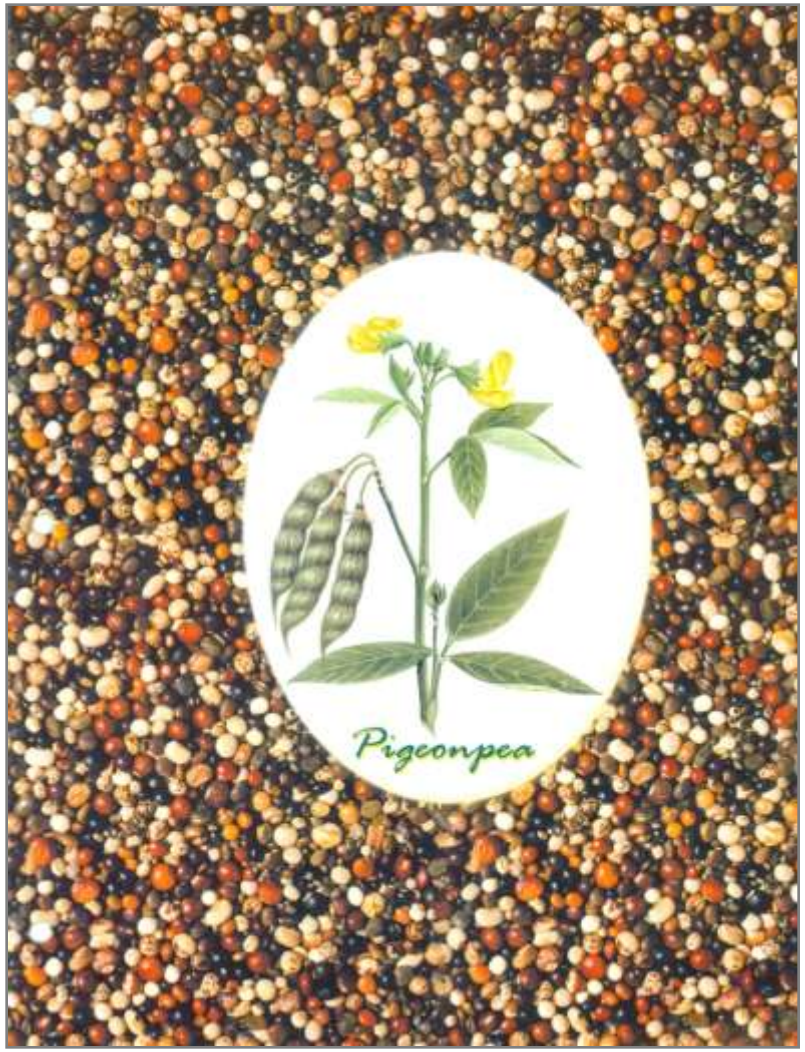
Trait	Accessions	
	Screened	Identified
Wilt resistance	15000	1136
Ascochyta blight resistance	3000	192
Botrytis gray mold resistance	2400	49
Colletotrichum blight resistance	9000	72
Pod borer resistance	16346	20
Drought tolerant	1000	11
Cold tolerant	1000	16
Salinity tolerant	1000	4

Chickpea germplasm lines released as varieties

Chickpea germplasm released as varieties					
Accession number	Country of origin	Country of release	Released name	Year of release	Remarks
ICC 4923	India	India	Jyothi	1978	
ICC 552	India	Myanmar	Yezin 1		Twin poded
ICC 4951	India	Myanmar	ICC 4951		Twin podded
ICC 6098	India	Nepal	Radha	1987	Wilt resistant
ICC 8521	Italy	USA	Aztee		
ICC 8649	Afghanistan	Sudan	Shendi	1987	
ICC 11879	Turkey	Syria	Ghab 1	1982	
ICC 11879	Turkey	Turkey		1986	
ICC 11879	Turkey	Algeria		1988	
ICC 11879	Turkey	Morocco		1987	
ICC 237	India	Oman	ICC 237	1988	
ICC 13816	USSR (former)	Algeria	Yialousa	1984	
ICC 13816	USSR (former)	Italy	Sultano	1987	
ICC 13816	USSR (former)	Syria	Ghab 2	1986	
ICC 13816	USSR (former)	Cyprus			
ICC 14911	USSR (former)	Turkey		1986	Tall, upright
ICC 14911	USSR (former)	Morocco		1987	
ICC 4998	India	Bangladesh	Bina-Sola 2	1994	
ICC 14880	India	Australia	Hira	1997	
ICC 3274	Iran	Bangladesh	Bari Chhola7	1999	
ICC 4944	India	Myanmar	Keyhman		

Pigeonpea biodiversity at ICRISAT genebank

- It is the sixth most important food legume grown in about 4.4 million ha.
- Widely adaptable and plays an important role in sustainable agriculture
- It is a multipurpose crop and a good source of vegetarian protein, used as soil enricher, fodder, fuel wood, for fencing, thatching, rearing lac insects, soil binder etc.
- About 92% of the area is in developing countries



Movement of Pigeonpea

- **Originated in India (primary centre).**
- **Spread to Africa (Secondary centre).**

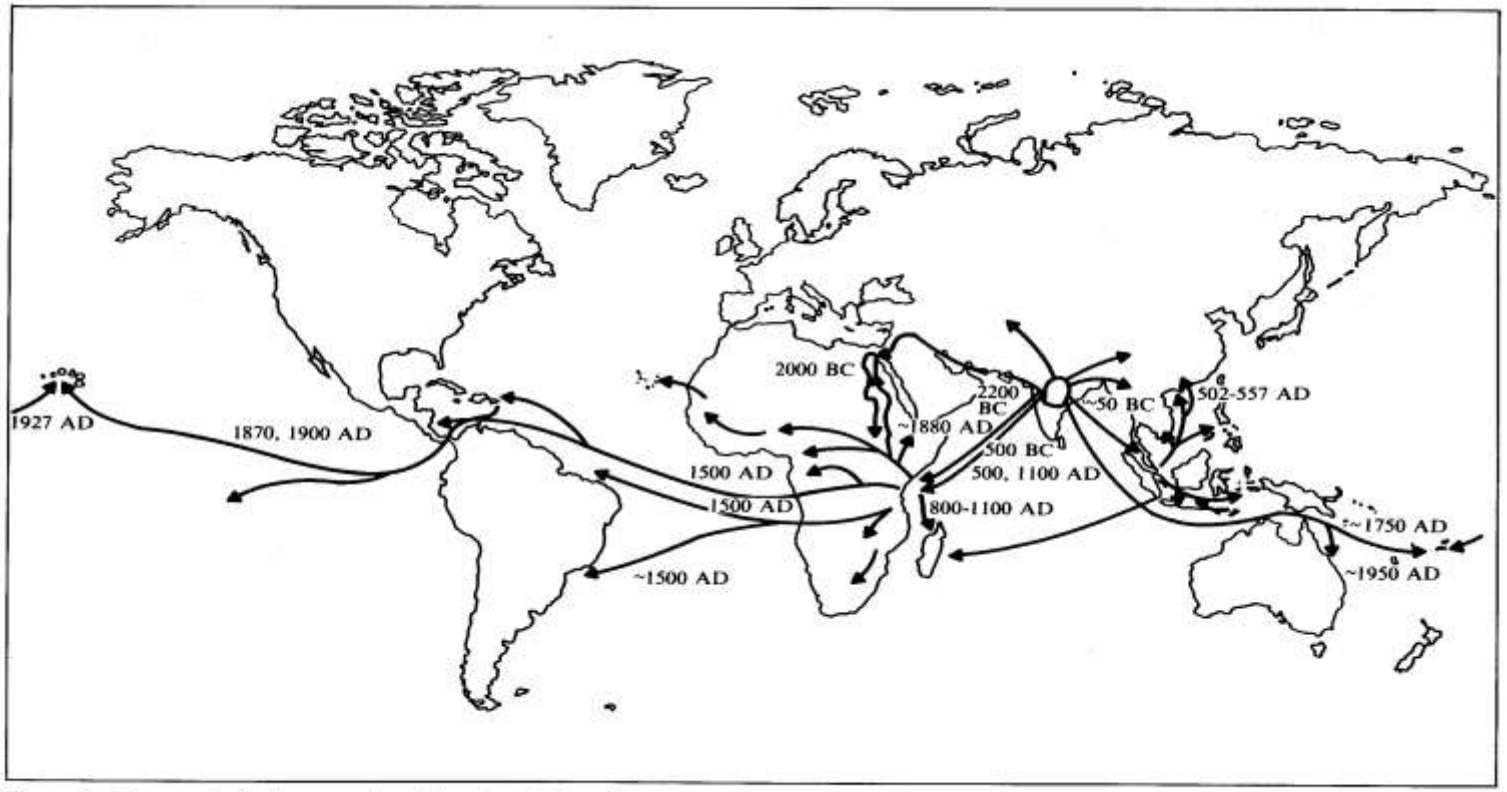
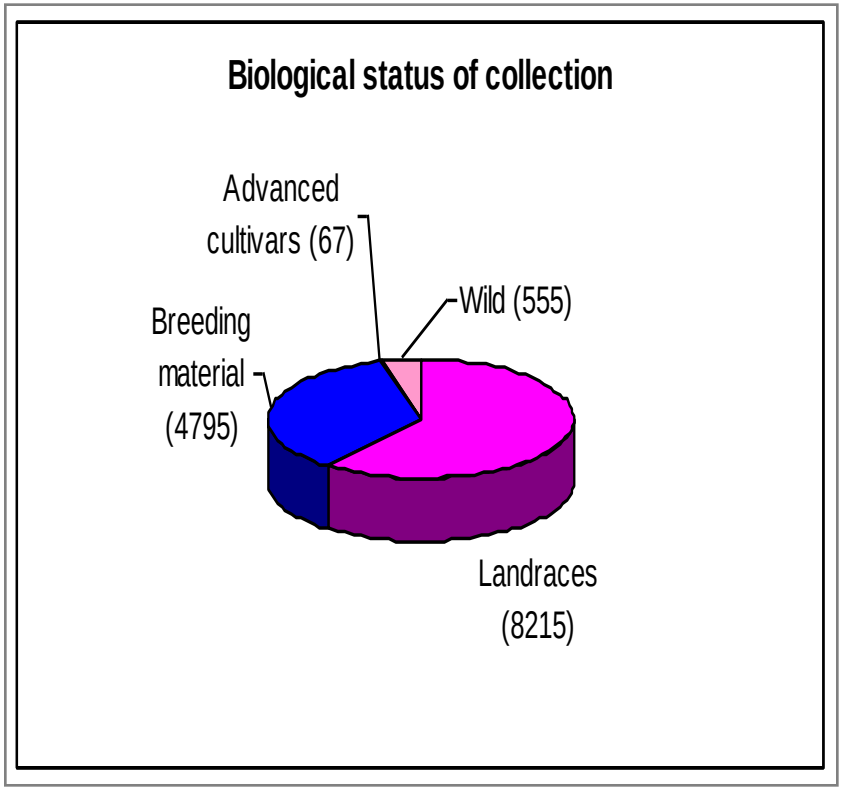


Figure 1. Movement of pigeonpea from its center of diversity.
Source: van der Maesen, 1980.

Pigeonpea germplasm assembled at ICRISAT genebank

- Number of accessions : 13,632
- Number of countries : 74
- Cultivated : 13,077
- Wild : 555
- Collections : 3,943
- Introductions : 9,689



Pigeonpea germplasm regeneration at ICRISAT

- Because of cross pollination, regeneration of pigeonpea is difficult and costly
- Developed new regeneration method of growing pigeonpea germplasm under insect proof cages
- This method is cost effective and we can produce more seed of good quality to reduce the regeneration frequency of accessions

Pigeonpea characterization and utilization at ICRISAT genebank

To enhance the utilization of germplasm:

- Characterized 95% of total collection
- Evaluated trait specific germplasm sets at different locations in different countries
- Organized field days facilitating the selection of germplasm by researchers

Contd…

Pigeonpea characterization and utilization at ICRISAT genebank

- Developed core and mini core collections for easy and efficient utilization of germplasm
- Developed composite collection and identified genetically most diverse reference set
- Developed trait-specific genepools to provide partially converted genotypes
- Identified several sources of resistance to abiotic and biotic stresses and useful traits

Range of variation in the pigeonpea collection at ICRISAT

Character	Mean	Minimum	Maximum
Days to 50% flowering	133.5	52	237
Days to 75% maturity	192.1	100	299
Plant height (cm)	177.9	39	310
Primary branches (no.)	13.5	1	107
Secondary branches (no.)	31.3	0	145.3
Tertiary branches (no.)	8.8	0	218.7
Racemes per plant (no.)	150.3	6	915
Pod length (cm)	5.7	2.5	13.1
Pods per plant (no.)	287.3	9.3	1819.3
Seeds per pod (no.)	3.7	1.6	7.2
100-seed weight (g)	9.3	2.7	25.8
Seed protein (%)	21.3	13	30.8

Promising pigeonpea germplasm sources identified for biotic and abiotic stresses at ICRISAT

Stress	Cultivated	Wild	Total
Nematodes	9		9
Pod borer	27		27
Pod fly	21		21
Pod borer and pod fly	6		6
Phytophthora blight	148	4	152
Alternaria blight	19	6	25
Sterility mosaic disease (SMD)	362	35	397
Stem canker and Root-rot	26		26
Wilt	87	20	107
Drought tolerant	7		7
Salinity tolerant	36	15	51
Water logging tolerant	5		5

Promising pigeonpea germplasm sources identified for special traits at ICRISAT

Trait	Total
Photoperiod insensitive	64
Dwarf	8
High nodulation	4
High seed protein content (>25%)	480
Suitable for agroforestry	21
Suitable for forage	13
Vegetable type	51
Accessions with 8-9 seeds per pod	10

Promising pigeonpea wild relatives identified for useful traits at ICRISAT

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Species	No. of accessions	Useful traits
C. albicans	20	Resistance to SMD, tolerant to drought and salinity
C. lineatus	10	Resistance to SMD and alternaria blight, drought tolerance
C. reticulatus	5	Resistant to pod borer, high seed protein content (33%).
C. scarabaeoides	100	Early flowering, resistance to major pests and diseases and salinity tolerant.
C. sericeus	4	Resistance to pests and diseases, tolerant to drought and salinity.
C. platycarpus	17	Extra early flowering (35 days).
C. acutifolius	12	Drought and salinity tolerant.

ICRISAT pigeonpea germplasm released as varieties

ICP Number	Country of origin	Country of release	Released name	Year of release
6997	India	Nepal	Rampur Rhar	1992
7035	India	Fiji	Kamica	1985
7035	India	Philippines		1989
7035	India	China	Guimu 4	2003
8863	ICRISAT	India	Maruti	1985
9145	Kenya	Malawi	Nandolo wa Nswawa	1988
9905	India	Venezuela	La Cerrera	1991
11384	Nepal	Nepal	Bageshwari	1992
11916	India	Venezuela	Aroa	1991
13829	Granada	Venezuela	Cerro Pelon	1991
14770	ICRISAT	India	Abhaya	1989

Impact of ICRISAT pigeonpea germplasm released as varieties

- Conserving and making available the valuable germplasm itself is the great impact
- ICP 8863, a medium-duration, wilt-resistant variety released as “Maruti” in Karnataka, India in 1985
- In Maharashtra, a neighboring state, it was sown on more than 50% of total wilt-affected districts
- Yield gains of ICP 8863 over the best available cultivar was about 50%
- Net value of benefits from fusarium wilt research is approximately US$ 75 million representing an internal rate of return of 73% (ICRISAT Asia Region Annual Report 1995)

Groundnut biodiversity at ICRISAT genebank

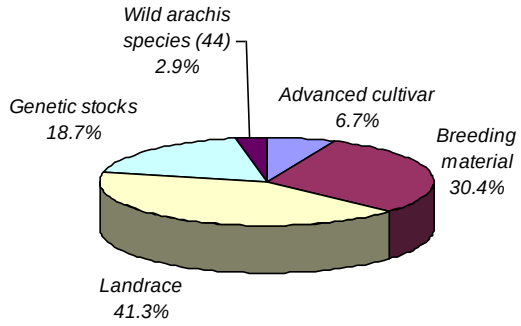
- Important oilseed crop grown for high quality edible oil (36-54%) and easily digestible protein (12-36%) in 113 countries on 23.4 million ha (FAO 2007)
- Over two-thirds global production occurs in seasonally rainfed regions
- Africa and Asia produced 91.4% of world groundnut (in shell) in 95.5% area
- Genebanks across the globe holds over 81000 accessions, 19% (15419) of these are in ICRISAT genebank

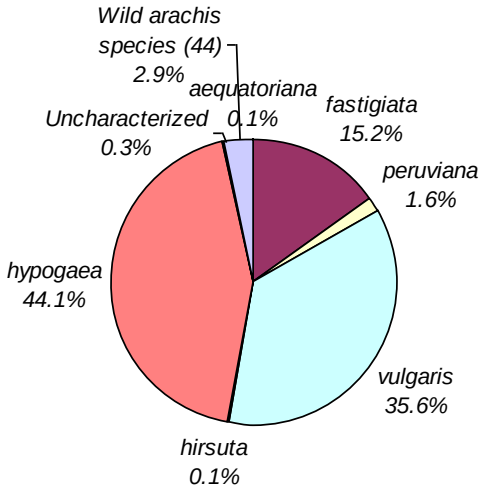
Groundnut origin and biology

- Center of origin - Chaco region between southern Bolivia and northwestern Argentina
- *Genus Arachis* comprises 80 species placed in 9 sections. Section *Arachis* contains cultivated groundnut
- *Arachis* hypogaea is a tetraploid with 2n=40 chromosomes.
- Most wild *Arachis* species are diploid

Groundnut germplasm at ICRISAT genebank

- Accessions:15,419
- Countries : 92
- Cultivated : 14,968
- Wild : 451
- Collection : 2,776
- Introduction: 12,643





Groundnut characterization and evaluation at ICRSAT

- Characterized for 15 morphological,14 agronomic, protein and oil contents, and major biotic and abiotic stresses
- Assessed phenotypic and geographical patter of diversity
- Developed core (1704 acc.), mini core (184 acc.) composite collection (1000 acc.), and reference set (300 acc.) to enhance groundnut germplasm utilization in crop improvement
- Identified trait-specific germplasm

Range of morphological descriptors in groundnut germplasm at ICRISAT

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Character	Range	Intermediate
Grow th habit	Errect-Procumbent	Decumbent
Branching pattern	Sequential-Alternate	Irregular
Stem pigmentation	Absent-Present	-
Stem hairness	Glabrous-Woolly	Hairy
Peg color	Absent-Present	-
Standard petal color	Yellow -Garnet	Orange
Standard petal markings	Yellow -Garnet	Orange
Leaf color	Yellow ish green-Dark green	Green
Leaflet shape	Cuneate-Lanceolate	elliptic
Hairness on leaflet	Sub-glabrous-Profuse and long	Scare and short
Pod beak	Absent-Very prominent	Moderate
Pod constriction	Absent-Very deep	Moderate
Pod reticulation	Smooth-Very prominent	Moderate
Seed color pattern	One-Verigated	-
Seed color	Off w hite-Dark purple	Tan

Range, means, and variance in groundnut collection at ICRISAT

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Character	Rainy season			Postrainy season		
	Range	Mean	Varaince	Range	Mean	Varaince
Days to emergence (number)	5-20	8.5	2.4	5-20	12.1	3.1
Leaflet length (mm)	15-86	52.5	68.5	15-94	53.3	97.0
Leaflet width (mm)	7-41	23.4	13.1	8-54	24.8	20.9
Days to flowering (number)	15-45	25.0	14.4	20-60	37.3	30.0
Pod length (mm)	12-70	28.7	26.2	14-70	30.4	26.0
Pod width (mm)	6-19	12.3	2.2	8-30	13.2	2.6
Seed length (mm)	8-33	13.3	4.5	6-23	14.1	4.9
Seed width (mm)	5-16	7.8	0.7	5-18	8.7	0.7
Seed weight (g)	14-120	43.1	129.7	15-140	51.5	166.3
Shelling percentage	29-87	67.4	58.7	30-87	70.1	47.8
Plant height $^{-1}$				4-71	27.5	103.5
Primary branches number $^{-1}$				3-14	5.7	3.2
Pod yield (kg/ha) $^{-1}$				100-6270	1740.3	743291
Oil (%) $^{-1}$				31.8-55.0	43.8	7.0
Protein content (%) $^{-1}$				15.5-34.2	25.7	6.1

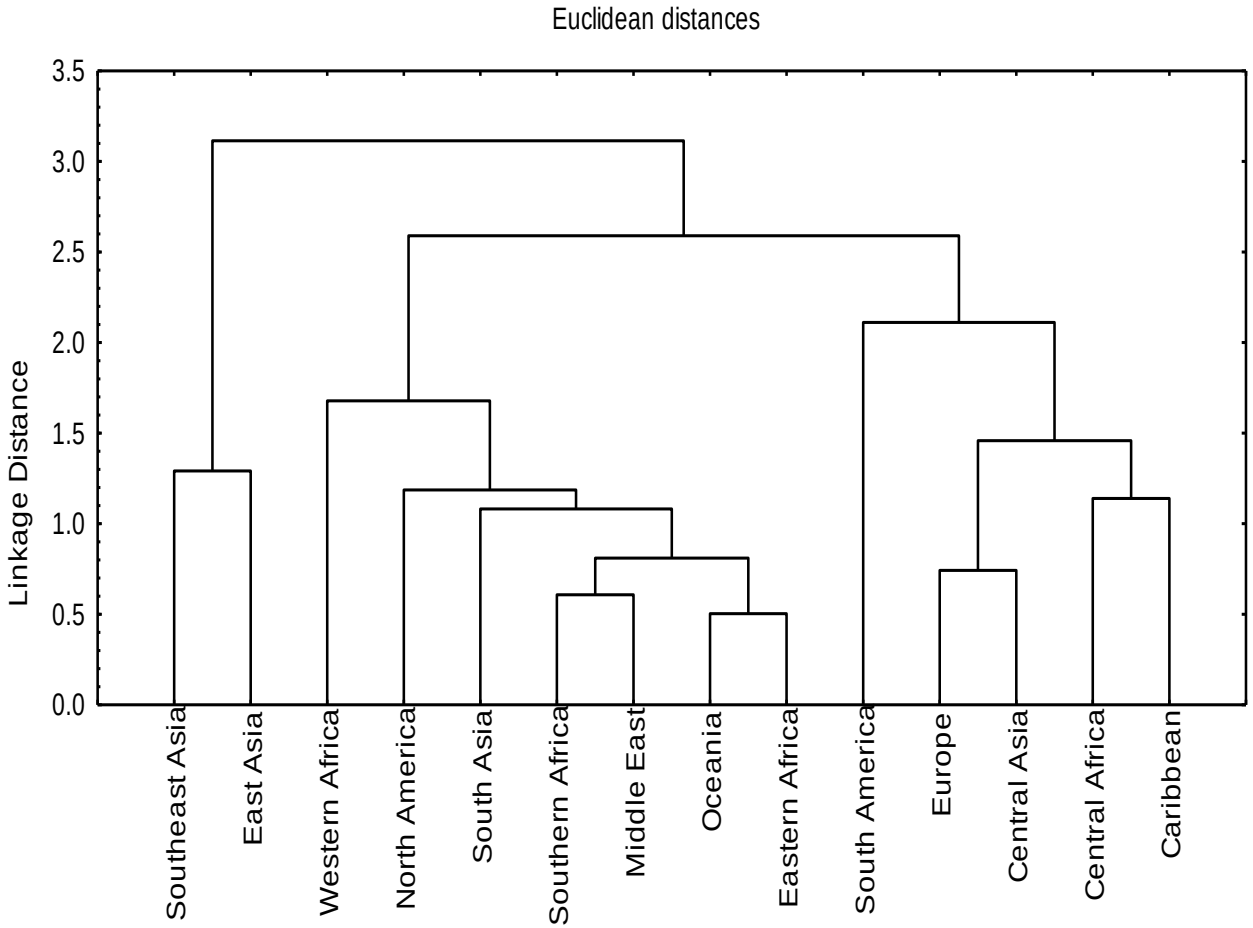
1= in either season

Geographical pattern of diversity in groundnut collection at ICRISAT

- 13,342 accessions from 92 countries
- 16 morphological, 10 agronomic in two seasons, and reaction to early leaf spot and groundnut rosette virus
- Fourteen regions
  - five in Asia-East, Central, South, Southeast, and Middle east
  - Four in Africa-Eastern, Central, Southern, and western
  - Three in Americas-North, South, and Caribbean
  - one each in Europe and Oceania

- Var. *fastigiata* - 2121 (15.9%), *vulgaris*-35.6, var *hypogaea*-6194 (46.4), var. *aequatoriana*-15 (0.1%) and var. *hirsuta*-20 (0.15%)%) accessions

Diversity in groundnut germplasm at ICRISAT genebank



Dendogram of 8 economical varieties of 38 traits and 14 regions in entire peanut

Groundnut germplasm accessions evaluated for various stresses at ICRISAT

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Traits	Number of accessions screened	Number of accessions with desirable traits	Traits	Number of accessions screened	Number of accessions with desirable traits
Disease resistance			Jassids	6500	30
Late leafspot	9400	76	Termites (Scarification)	520	20
Early leafspot	10567	9	Aphids	300	4
Rust	9400	142	Leafminer	930	18
Late leafspot and rust	9400	30	Spodoptera spp.	120	4
Bud necrosis	7400	23	Helothis spp.	145	10
Peanut mottle virus	1800	2	Others		
Seed invasion by *A. flavu*	582	17	Drought	742	38
Pod rot	3222	24	Biological nitrogen fixati	342	4
Insect tolerant			High oil content	8868	51
Thrips	5000	14	High protein content	8869	55

ICRISAT groundnut germplasm lines released as varieties

Identity	Country of origin	Country of release	Released name	Year of release
ICG 221	India	Swaziland		1994
ICG 273	Argentina	Ethiopia	Sedi	1994
ICG 1697	Peru	Indonesia	Singa	
ICG 1703	Peru	Indonesia	Panter	
ICG 2271	USA	Nepal		
ICG 2974	Israel	Tanzania	Johri	1985
ICG 2974	Israel	Myanmar	Sinpadetha 3	1984
ICG 7794	USA	Ethiopia		1989
ICG 7827	India	Philippines	UPL Pn 10	1992
ICG 7827	India	Myanmar	Sinpadetha 2	1984
ICG 7886	Peru	Jamica	Cardi-Payne	1987
ICG 12991	India	Uganda	Serenut 4T	2002
ICG 12991	India	Malawi	Baka	2001

Small millets at ICRISAT genebank

Small millets used as food crops includes

- Finger millet [*Eleusine coracana* (L.) Gaertn.]
- Foxtail millet [*Setaria italica* (L.) P. Beauv.]
- Proso millet [*Panicum miliaceum* L.]
- Little millet [*Panicum sumatrense* Roth. ex Roem. & Schult.]
- Barnyard millet [*Echinochloa crusgalli* (L.) P. Beauv. & *Echinochloa colona* (L.) Link]
- Kodo millet [*Paspalum scrobiculatum* L.]

Special features of small millets conserved at ICRISAT genebank

- Hardiest crops grown in difficult production environments
- Relatively tolerant to stresses
- Important to global agriculture
- Stover serve as quality fodder for cattle
- Combined together cultivated on 18-20 m ha with a production of 15-18 m tons
- Fast maturing and highly water-use efficient crops
- Respond well to even small increments of fertilizer
- Rich in micronutrients more appropriate to call them "**Nutritious Millets**"

Finger millet

- Domesticated about 5000 years B.C. in Eastern Africa (Ethiopia)
- Introduced into India about 3000 years ago
- Staple food in parts of Eastern and Central Africa and India

Foxtail millet

- Domesticated in the high lands of Central China
- Yang-Shao period dating back some 5000 years
- Grown in southern Europe and in temperate, subtropical, and tropical Asia

Proso millet

- Domesticated in Manchuria
- Introduced into Europe about 3000 years ago followed by near East and India
- Particularly suited to dry conditions
- Grows in more varied temperature climates than other millets

Little millet

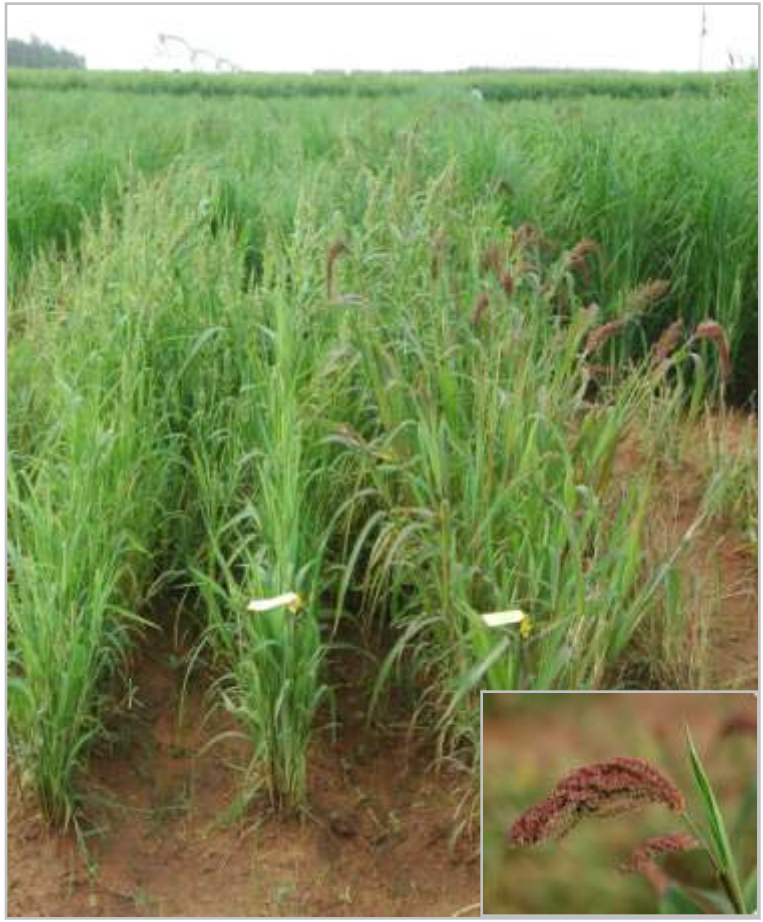
- Domesticated in India
- Represents weedy progenitor *P. psilopodium*
- Grown throughout India
- Altitudes of 2100 m

Kodo millet

- Domesticated in India, almost 3000 years ago
- Found across the old world in humid habitats of the tropics and subtropics
- Minor grain crop in India
- Important in the Deccan plateau

Barnyard millet

- *E. crusgalli* domesticated in Japan 4000 years ago
- *E. colona* domesticated in India
- Barnyard millet are fastest growing of all millets
- Produces a crop in six weeks



Small millets Germplasm holdings in ICRISAT genebank

Crop	Active collection	Base collection	Source countries
Finger millet	5,949	4,620	24
Foxtail millet	1,535	1,054	26
Proso millet	842	576	30
Little millet	466	384	5
Kodo millet	658	630	2
Barnyard millet	743	487	9
Total	10,193	7,751	50 (distinct)

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Nutritional value of small millets

Crop/Nutrituent	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Proso millet	12.5	2.2	1.9	0.8	14
Kodo millet	8.3	9	2.6	0.5	27
Little millet	7.7	7.6	1.5	9.3	17
Barnyard millet	11.2	10.1		15.2	11
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Impact of ICRISAT - supplied small millets germplasm

Varieties directly released from the material supplied by ICRISAT

- Finger millet - 2
- Barnyard millet - 1

Core collection of small millets at ICRISAT genebank

Crop	Entire collection (Number)	Traits used	Core collection (Number)	Reference
Finger millet	5,940	14	622	Upadhyaya et al., 2006
Foxtail millet	1,474	12	155	Upadhyaya et al., 2008 (Under review)

Reference set

- Finger millet - 300 accessions captured 89.2% of composite
- Foxtail millet – 200 accessions to be established


Thank you