

Plant Genetics and Breeding for Better Utilization of Native Agrobiodiversity in Nepal

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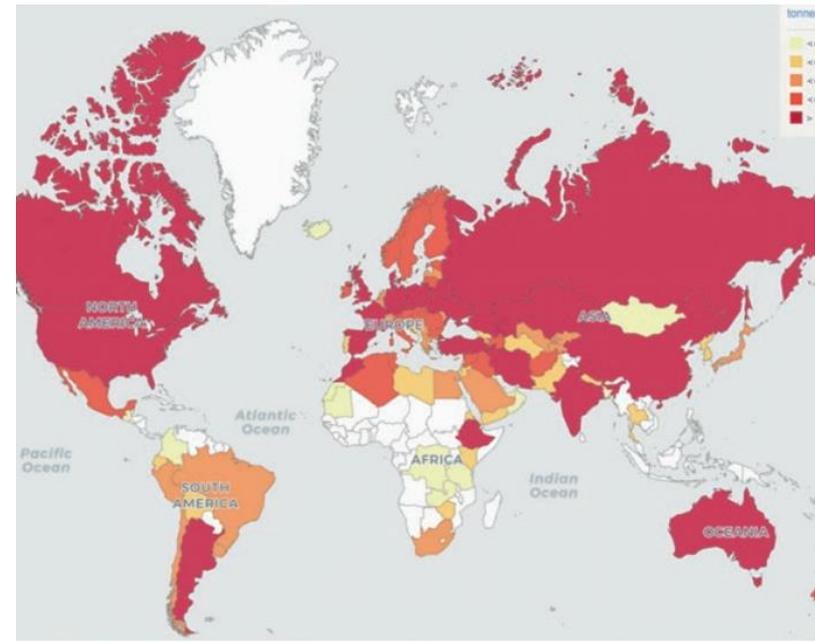
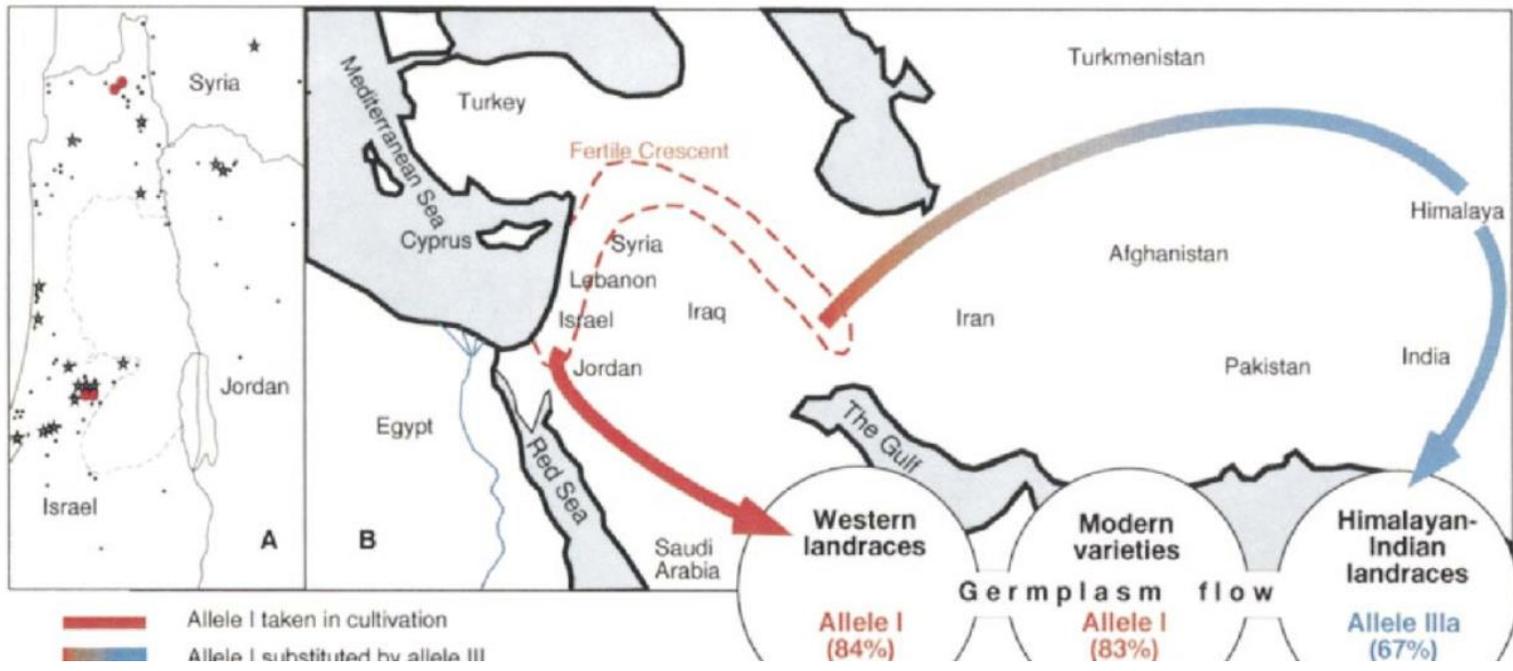
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Genetic resources

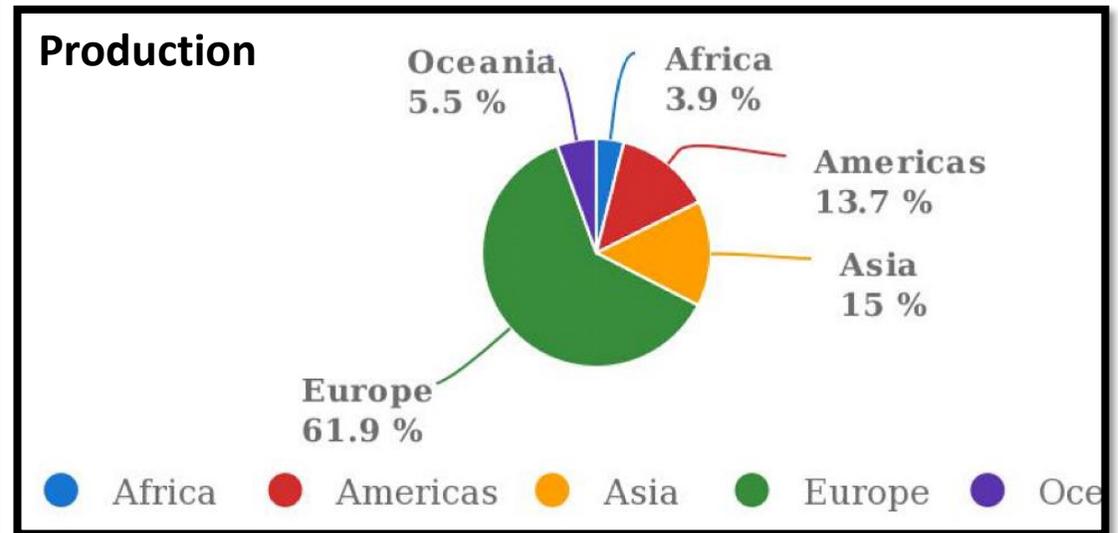
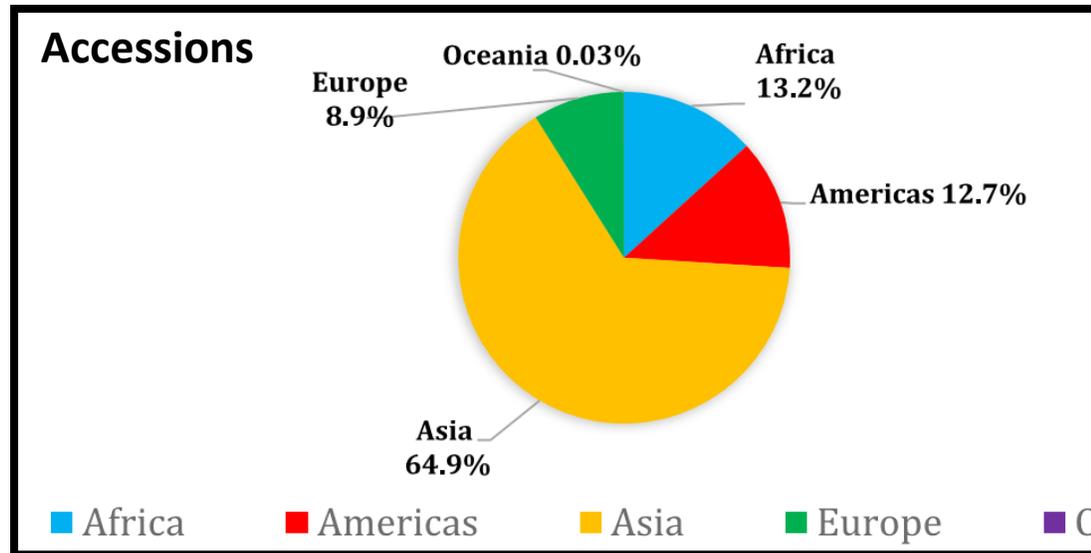
- Sources of germplasm and collection
- Maintenance, characterization, cataloging, and
- Utilization

- Nepal is very rich in Plant biodiversity (ca [2000 plant species](#)), which needs to be utilized for the benefit of Nepalese agriculture
- **Diversity within species**, diversity of different taxa, and diversity of ecosystem
- For breeding, diversity within species is important



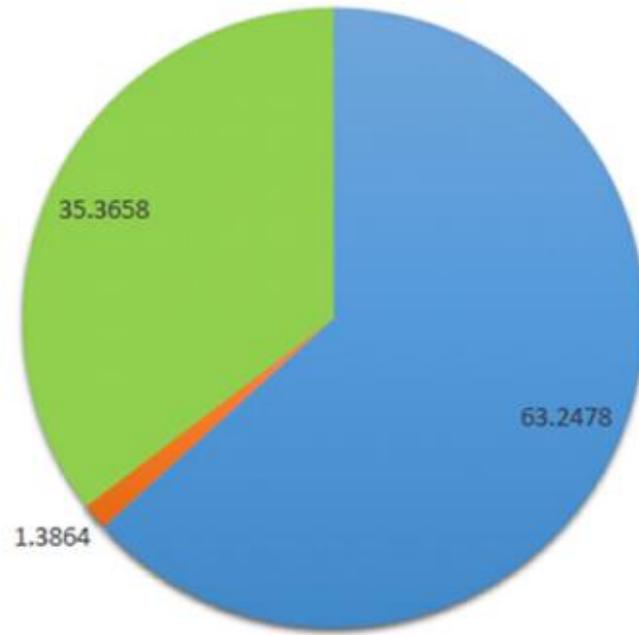
Naked barley

- One of the oldest crops in the world (>8,000 years record)
- Healthy nutrition profile



Quinoa

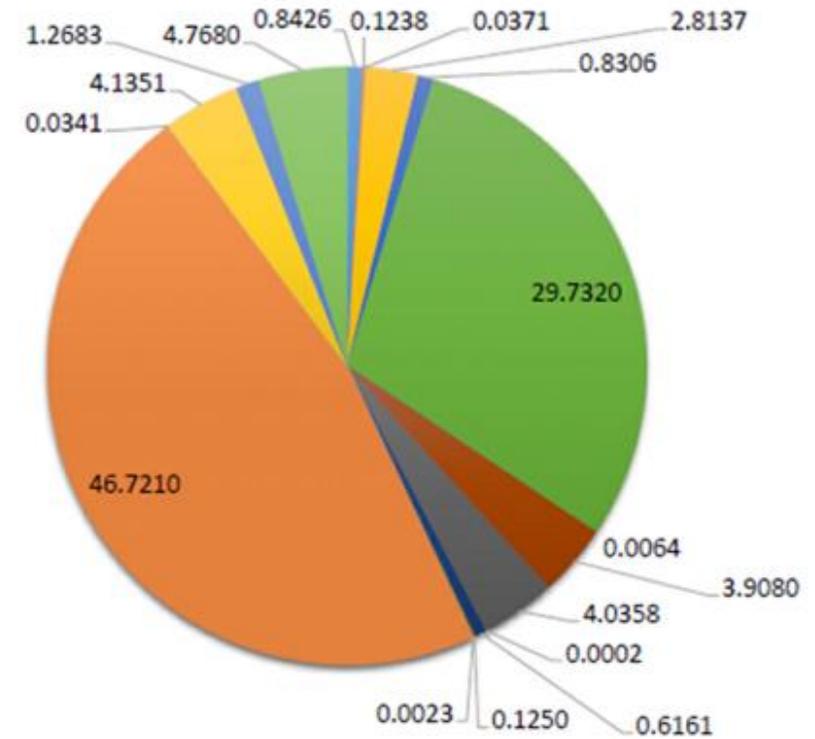
A



- Bolivia (Plurinational State of)
- Ecuador
- Peru

Buckwheat

B

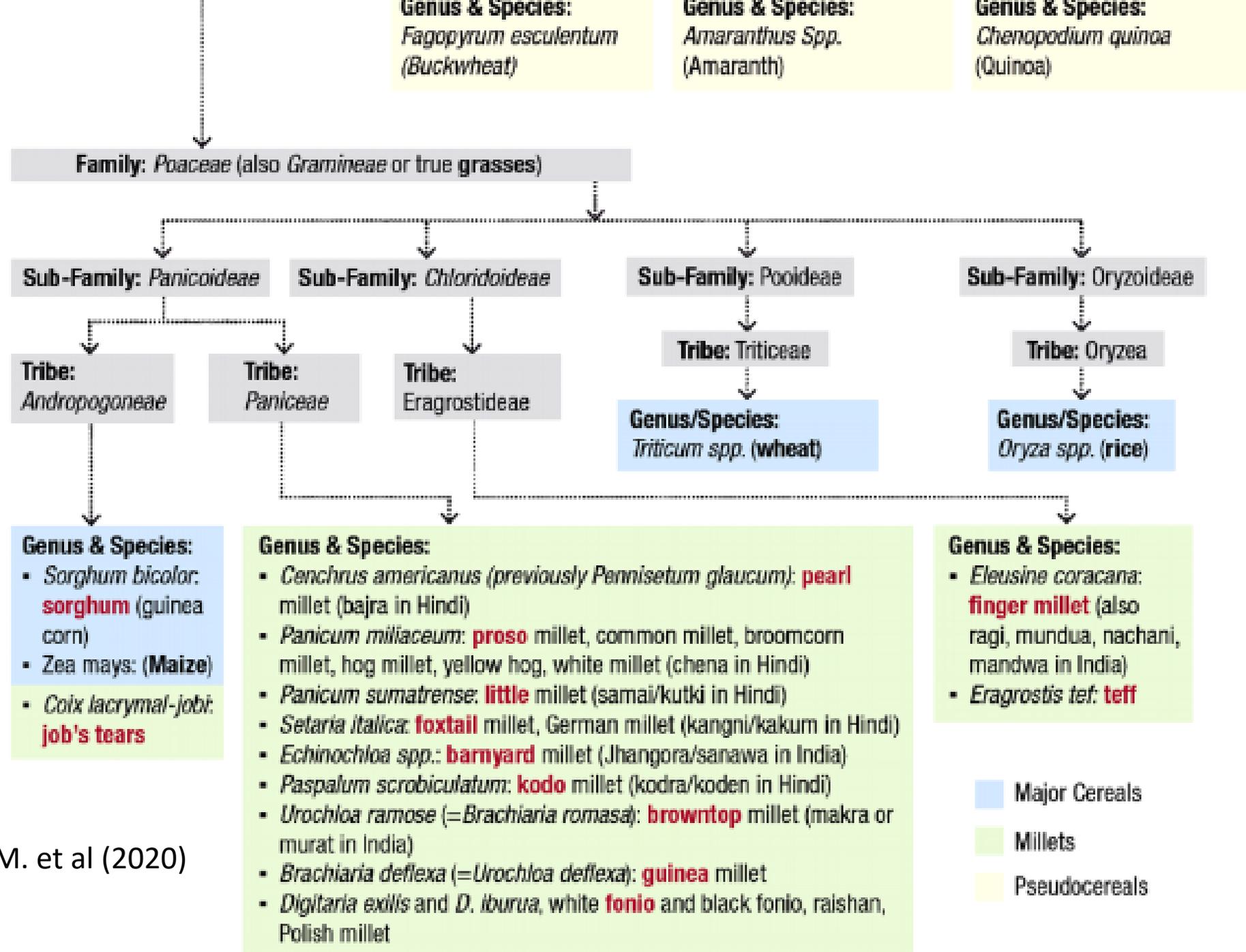


- Belarus
- Bosnia and Herzegovina
- Canada
- Georgia
- Kazakhstan
- Nepal
- Republic of Moldova
- South Africa
- United Republic of Tanzania
- Bhutan
- Brazil
- China
- Japan
- Kyrgyzstan
- Republic of Korea
- Russian Federation
- Ukraine
- United States of America



Finger Millet ~ *Eleusine coracana*





Crop	Scientific name	Chromosome number	Domestication	Distribution
Finger millet	<i>Eleusine coracana (L.)</i>	2n = 4x = 36, AABB	Ethiopia and Uganda	India, China, Nepal, Myanmar and Sri Lanka; Uganda, Kenya, Sudan, Eritrea, Zimbabwe, Zambia, Malawi, Madagascar Rwanda, Burundi
Foxtail millet	<i>Setaria italica (L.)</i>	2n = 2x = 18, AA	China, Europe and Afghanistan-Lebanon	India, China, Nepal Afghanistan, Korea, Japan, Russia, USA, France
Proso millet	<i>Panicum miliaceum L.</i>	2n = 4x = 36	China and Europe	India, China, Japan, Russia, Afghanistan, Iran, Iraq, Syria, Turkey, Mongolia, Romania, USA
Little millet	<i>Panicum sumatrense</i>	2n = 4x = 36, AABB	India	India, Nepal, Pakistan, Sri Lanka, Indonesia, Myanmar
Japanese barnyard millet	<i>Echinochloa crus-galli (L.)</i>		Japan	Korea, Japan, India
Indian Barnard millet	<i>Echinochloa colona (L.)</i>	2n = 6x = 54	India	
Kodo millet	<i>Paspalum scrobiculatum L</i>	2n = 4x = 40	India	India, Africa
Teff	<i>Eragrostis tef</i>	2n = 4x = 40, AABB	Ethiopia	Ethiopia, Eritrea, Kenya, South Africa, USA, Canada, Australia, Europe and Yemen. South Africa, Morocco, Australia, India and Pakistan

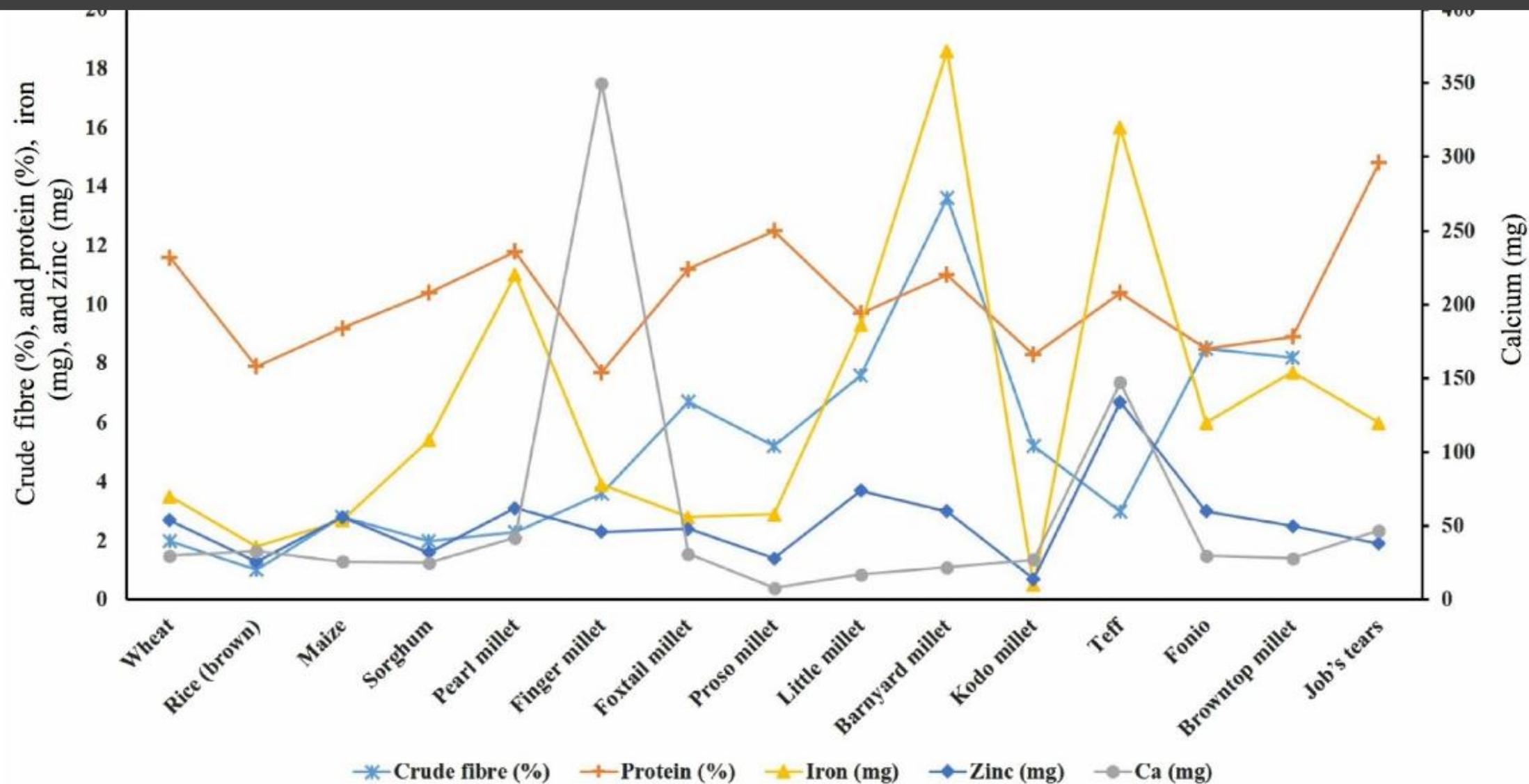


Fig. 1 Nutrient composition of small millets in comparison with major cereals (100 g edible part at 12% moisture) *Source:* [13, 46, 148, 185]; <http://krishikosh.egranth.ac.in/handle/1/5810027060>

Minor crops are rich in nutrients including proteins, and minerals

TABLE 1 | Nutritional composition of main millets in comparison to major cereals (@ 12% moisture; per 100 g edible portion).

Nutrients	Finger millet ^{1,2}	Pearl millet ^{1,2}	Foxtail millet ^{1,2}	Proso millet ^{1,2}	Wheat ^{1,2}	Rice (white, milled, raw) ^{1,2}	Rice (brown, medium grain, raw) ³	Corn grain (white) ³	Sorghum ³	Oats ³	Barley (pearled, raw) ³
Proximate composition											
Moisture (g)	13.1	12.4	11.2	11.9	12.8	13.7	12.4	10.4	12.4	8.2	10.1
Energy (kcal)	336	361	331	341	346	345	362	365	329	389	352
Protein (g)	7.7	11.6	12.3	12.5	11.8	6.8	7.5	9.4	10.6	16.9	9.9
Fat (g)	1.5	5	4.3	1.1	1.5	0.5	2.7	4.7	3.5	6.9	1.2
Total dietary fiber (g)	11.5	11.3	2.4	–	12.5	4.1	3.4	7.3	6.7	10.6	15.6
Carbohydrate (g)	72.6	67.5	60.9	70.4	71.2	78.2	76.2	74.3	72.1	66.3	77.7
Minerals (g)	2.7	2.3	3.3	1.9	1.5	0.6	–	–	1.6	–	–
Minerals and trace elements											
Calcium (mg)	350	42	31	14	30	10	33	7	13	54	29
Iron (mg)	3.9	8	2.8	0.8	3.5	0.7	1.8	2.7	3.36	4.7	2.5
Magnesium (mg)	137	137	81	153	138	64	143	127	165	177	79
Phosphorus (mg)	283	296	290	206	298	160	264	210	222	523	221
Manganese (mg)	5.94	1.15	0.6	0.6	2.29	0.51	–	–	0.78	–	–
Molybdenum (mg)	0.102	0.069	0.7	–	0.051	0.05	–	–	0.039	–	–
Zinc (mg)	2.3	3.1	2.4	1.4	2.7	1.3	2.02	2.21	1.7	3.97	2.1
Sodium (mg)	11	10.9	4.6	8.2	17.1	–	4	35	2	2	9
Potassium (mg)	408	307	250	113	284	–	268	287	363	429	280
Vitamins											
Thiamine (mg)	0.42	0.33	0.59	0.2	0.45	0.06	0.41	0.39	0.33	0.76	0.19
Riboflavin (mg)	0.19	0.25	0.11	0.18	0.17	0.06	0.04	0.2	0.096	0.14	0.11
Niacin (mg)	1.1	2.3	3.2	2.3	5.5	1.9	4.3	3.6	3.7	0.96	4.6
Total Folic acid (µg)	18.3	45.5	15	–	36.6	8	20	–	20	56	23
Vitamin E (mg)	22	–	–	–	–	–	–	–	0.5	–	0.02

(1) Gopalan et al. (1999).
 (2) Gopalan et al. (2004).
 (3) USDA National Nutrient Database for Standard Reference, Release 28 (2016).

- There is more than >60% reliance on rice, wheat and maize
- They have lower concentration of mineral nutrients
- We need to diversify the minor crops with more micronutrients
- Millets are rich source of such nutrients, which are under-utilized now
- Millets were originated from Africa, Asia, and Europe

Genotyped 579 accessions using 37 SSR to determine the population structure of **Proso millet**
 Investigated the total phenolic content and superoxide dismutase activity

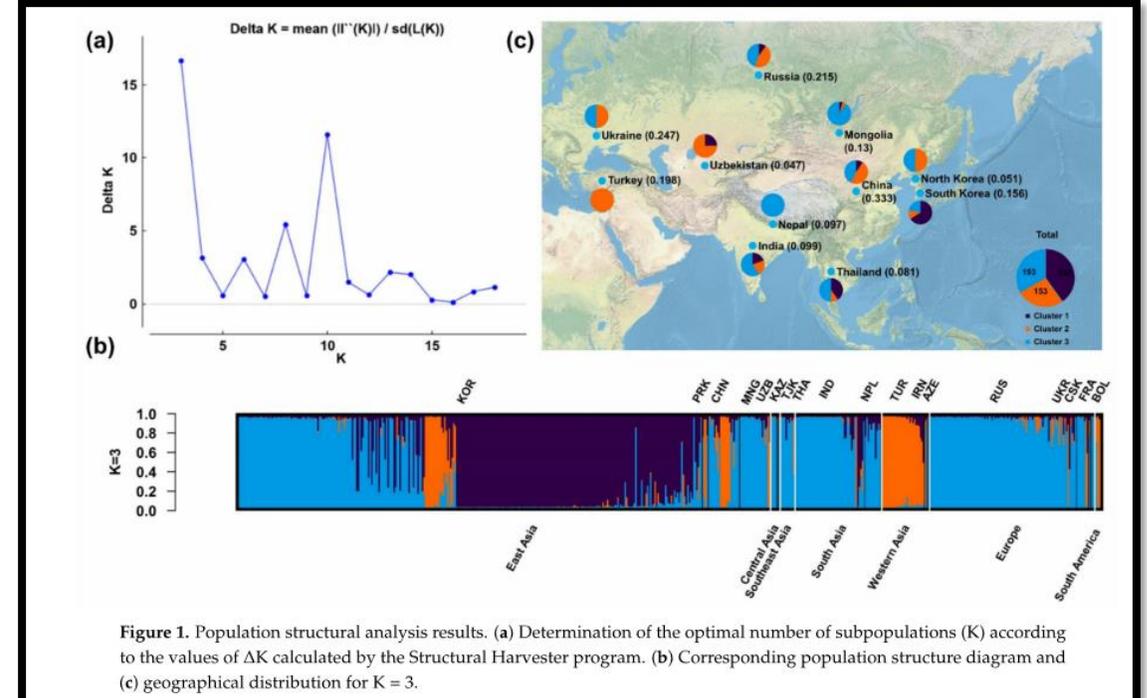
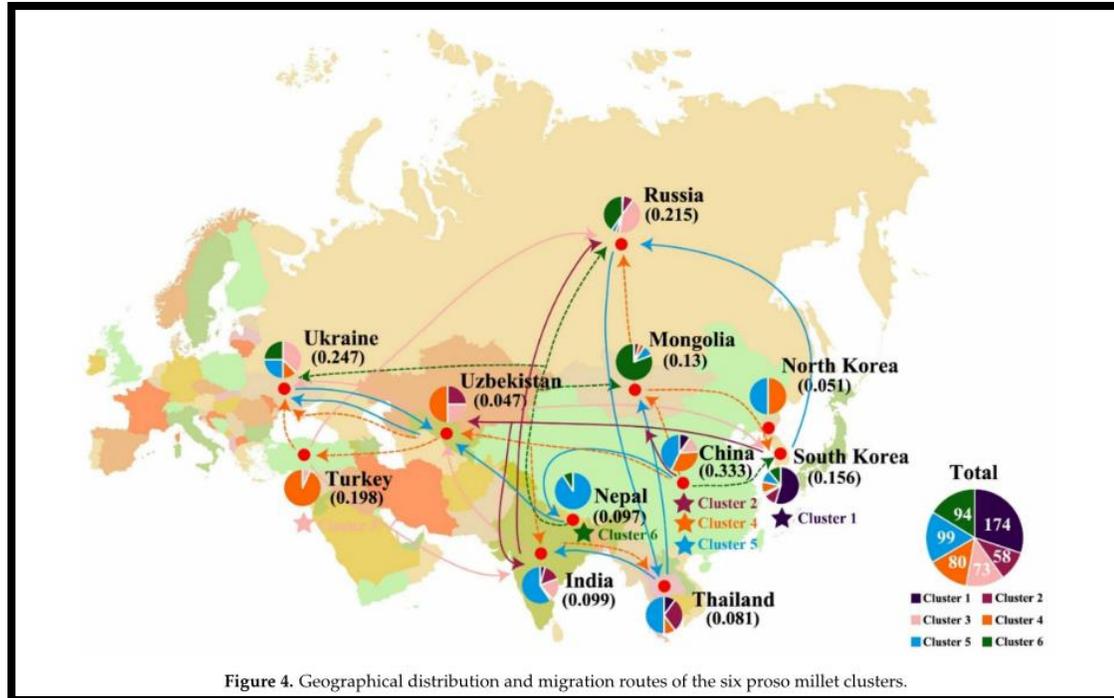
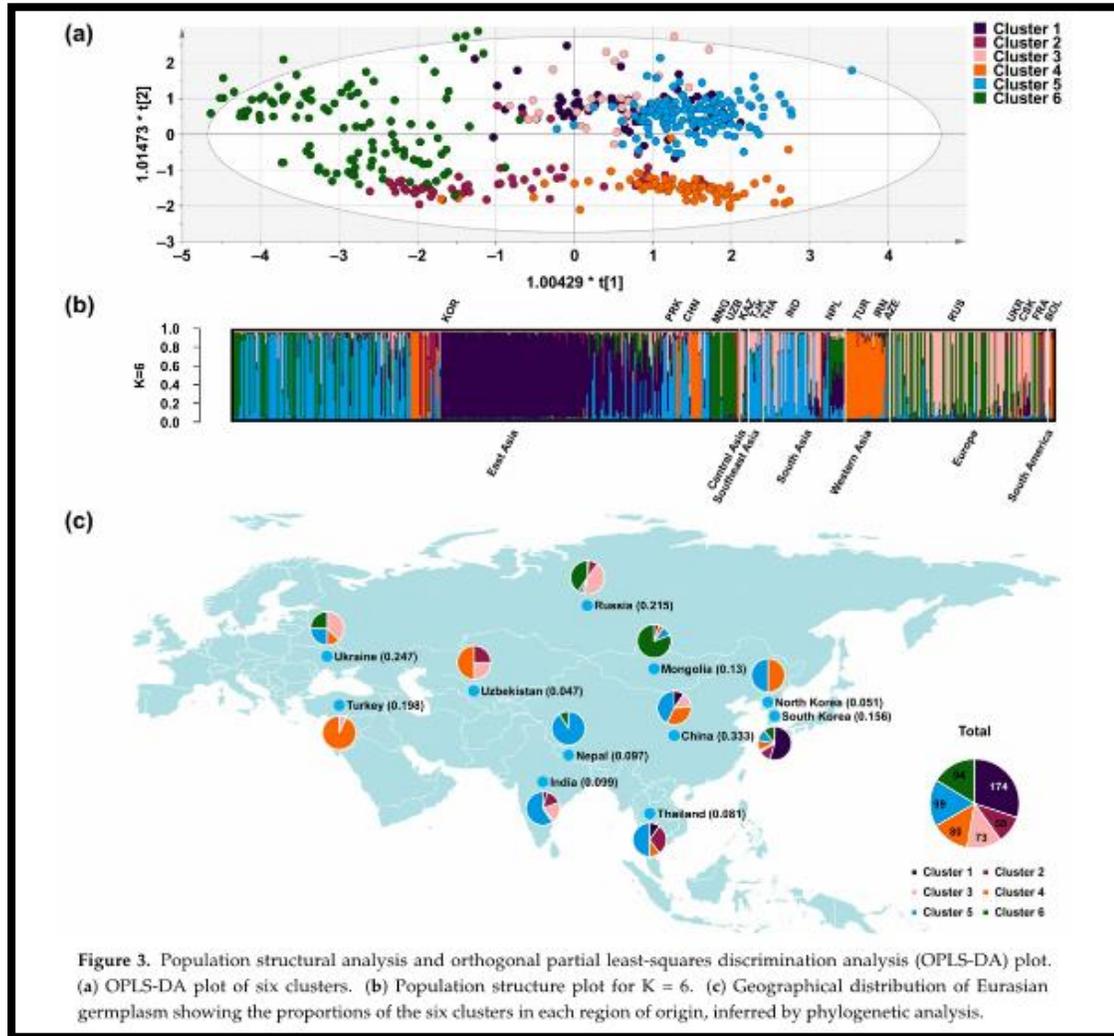
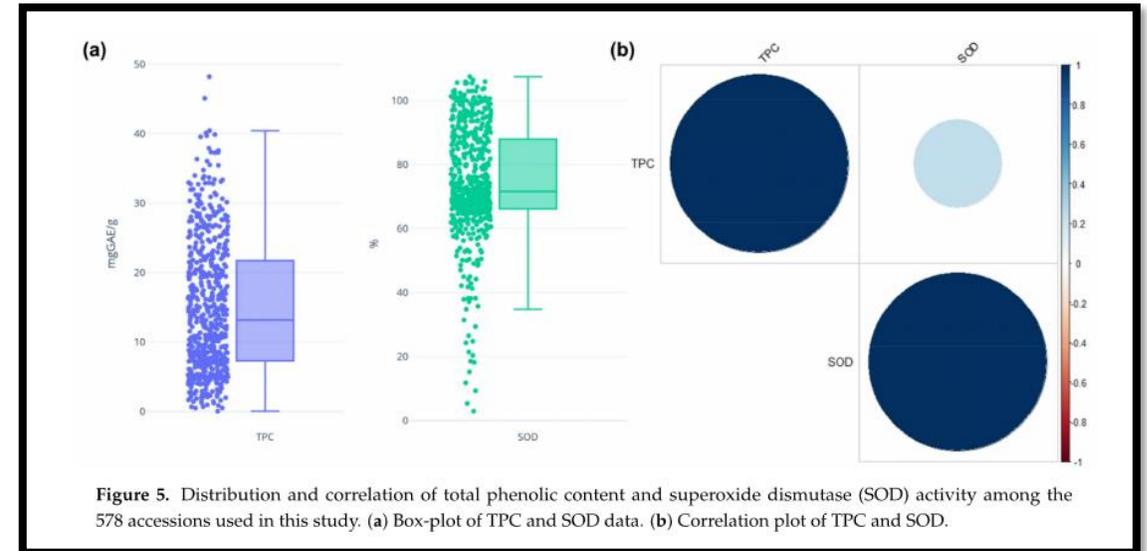


Figure 4. Geographical distribution and migration routes of the six proso millet clusters.

Figure 1. Population structural analysis results. (a) Determination of the optimal number of subpopulations (K) according to the values of ΔK calculated by the Structural Harvester program. (b) Corresponding population structure diagram and (c) geographical distribution for K = 3.



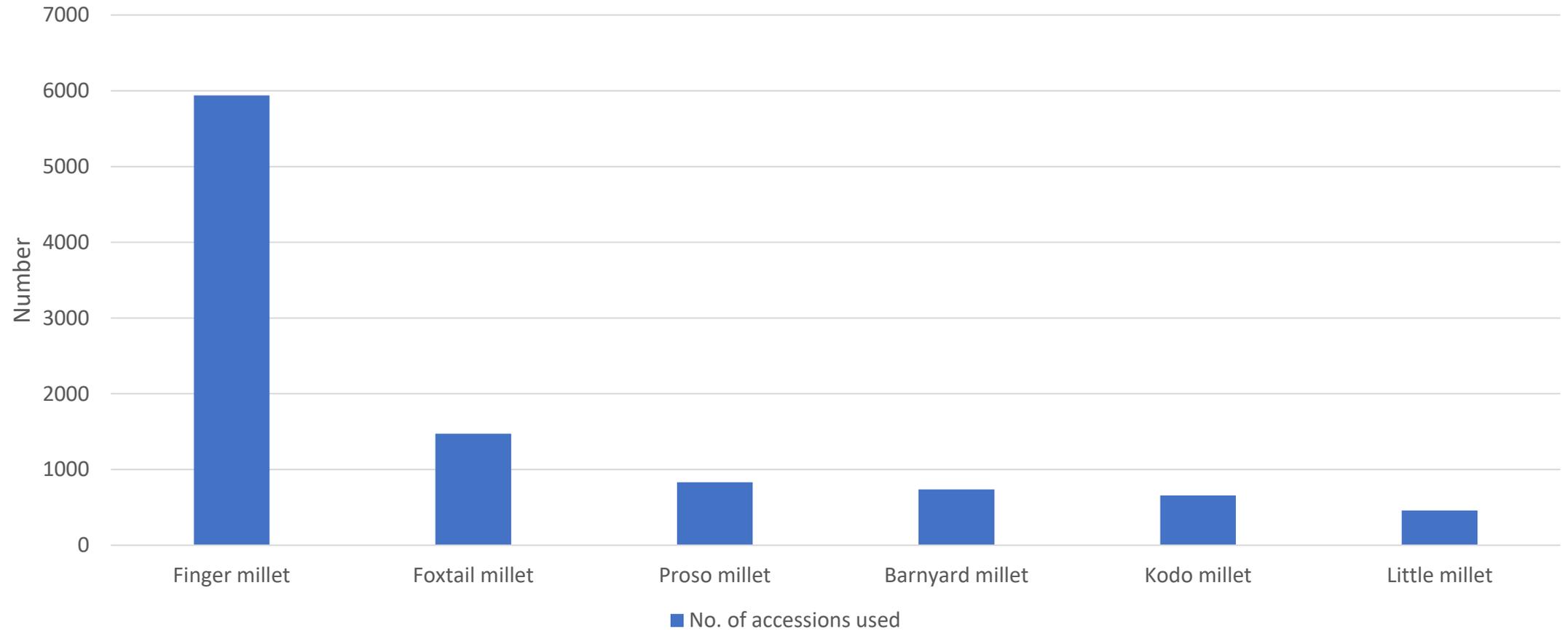
Six clusters identified, one of the clusters identified from Nepal, which was adapted to high altitude, and high latitude



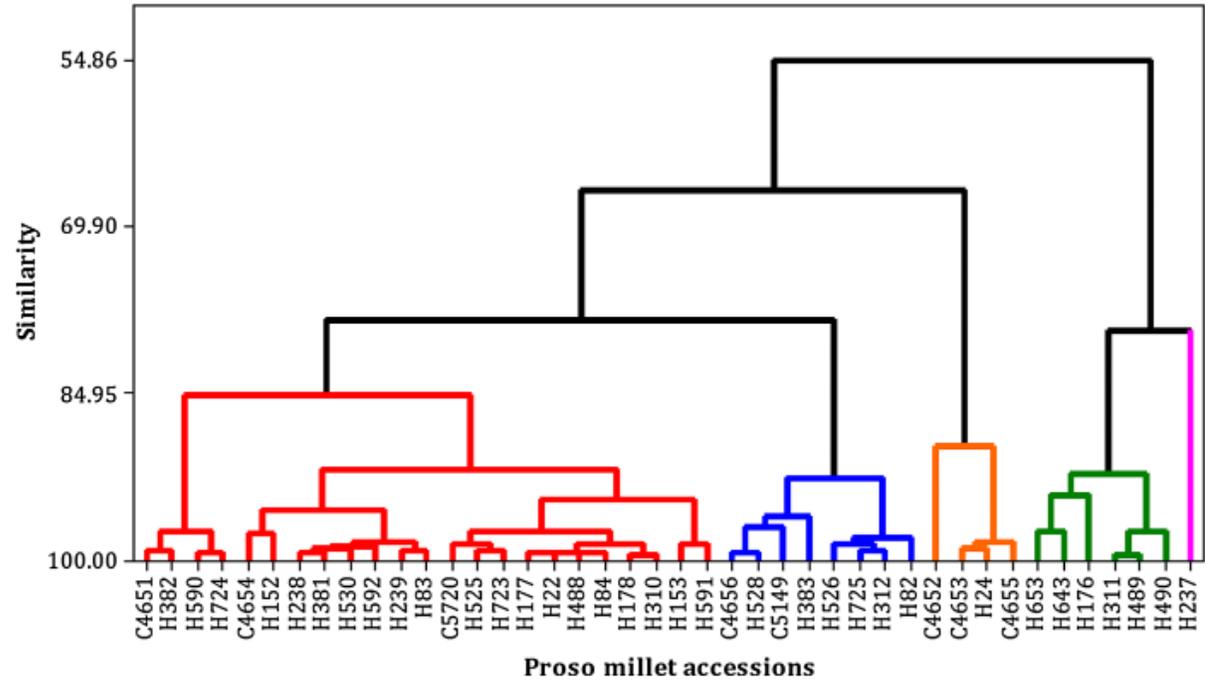
Wang, X. et al. (2021)

Genus	Africa	Asia	USA	Europe	Oceania	Total
<i>Eleusine</i>	8328	28919	1476	76	40	38839
<i>Setaria</i>	1142	38781	1486	4920	339	46668
<i>Echinochloa</i>	307	7815	387	61	60	8630
<i>Panicum</i>	3871	24539	3534	16489	371	48804
<i>Paspalum</i>	713	4233	3166	55	537	8704
<i>Eragrostis</i>	6384	638	1654	294	97	9067
<i>Digitaria</i>	1316	546	800	292	384	3338
<i>Coix</i>	3	288	26	42	4	363
<i>Urochloa</i>	677	102	1287	27	28	34

Core collection of germplasm

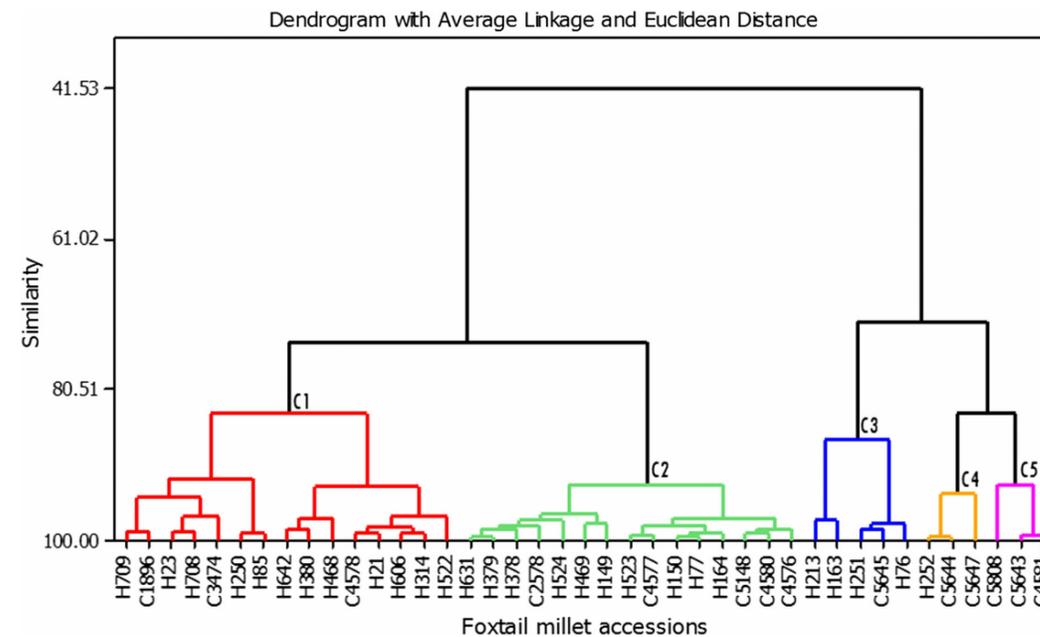
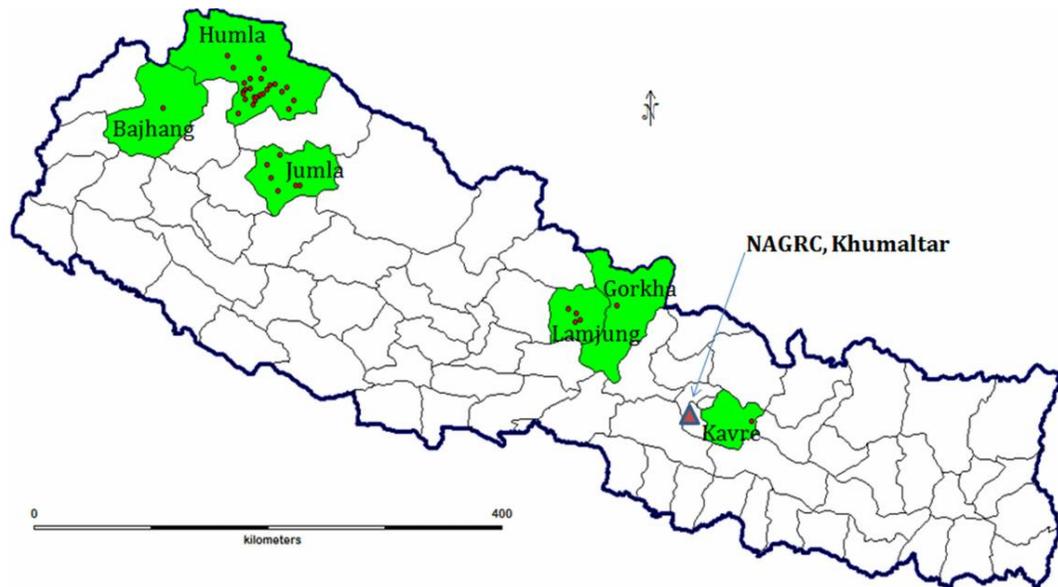


Collected 42 accessions of Proso millet from northwestern Nepal.
Shannon-Weaver Diversity Indices calculated



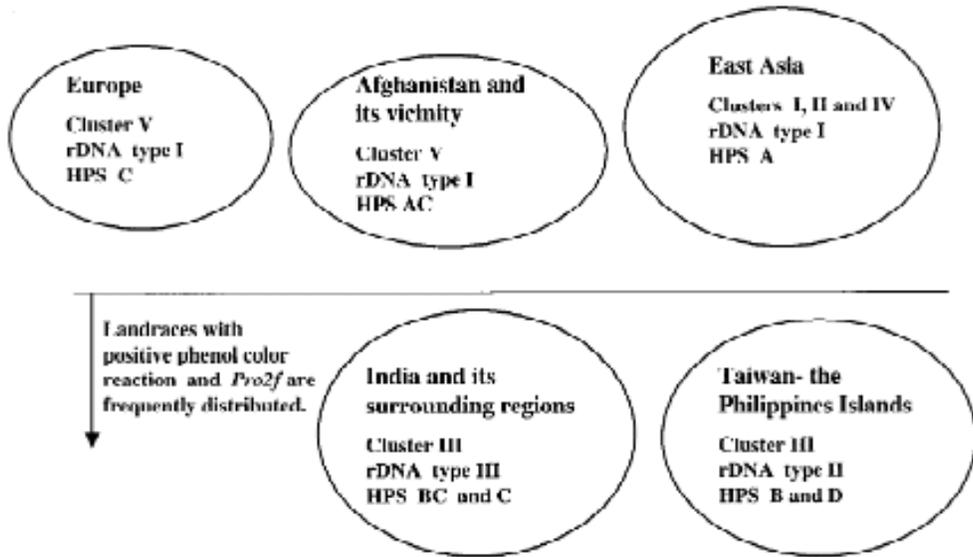
Analyzed 41 accessions of Foxtail millet collected from western Nepal.

Shannon-Weaver Diversity Indices calculated
High yielding accessions identified

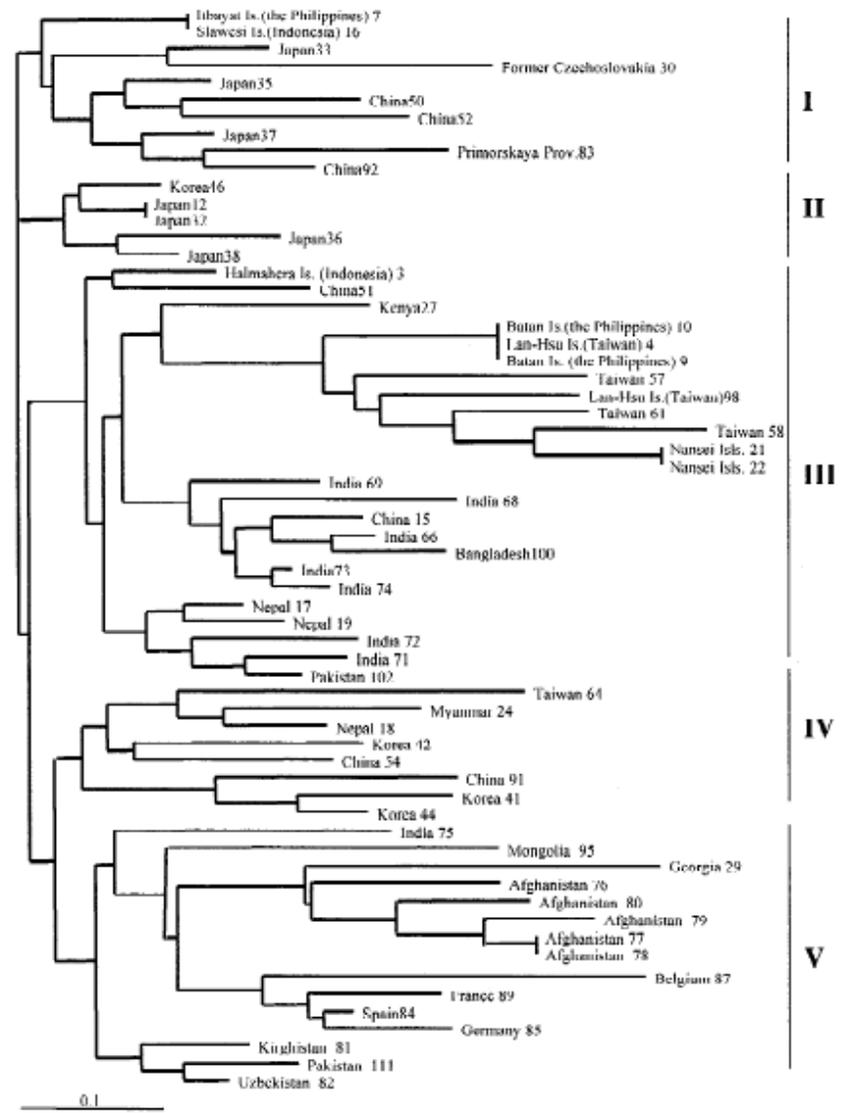


Ghimire, K.H. et.at., (2018)

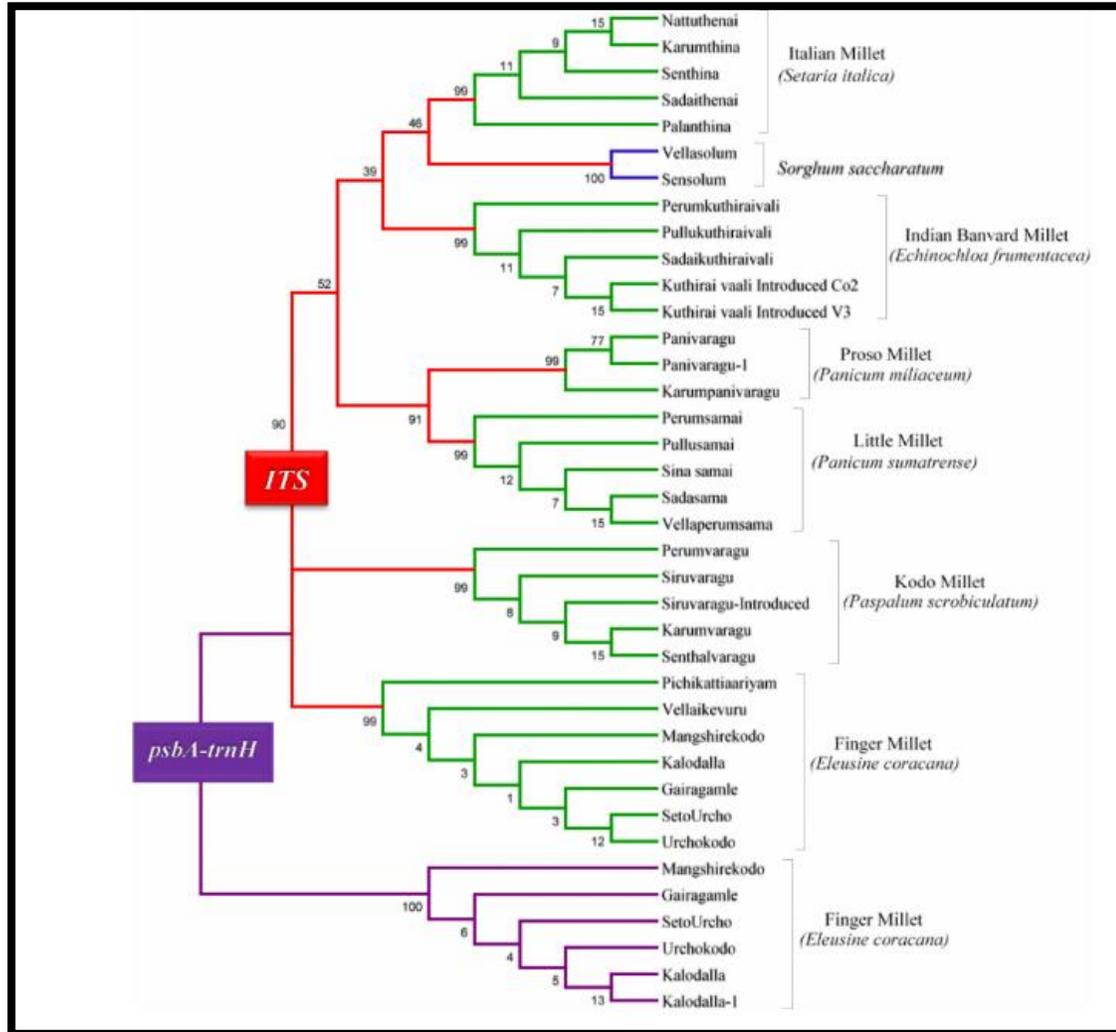
Diversity analysis of 62 accessions of Foxtail millet performed using 16 RFLP markers
 Identified five distinct clusters based on geographical origin



Fukunaga, F. et al. (2002)



Employed barcoding approach in 32 genotypes of multiple genera of millets from India and Nepal for conservation



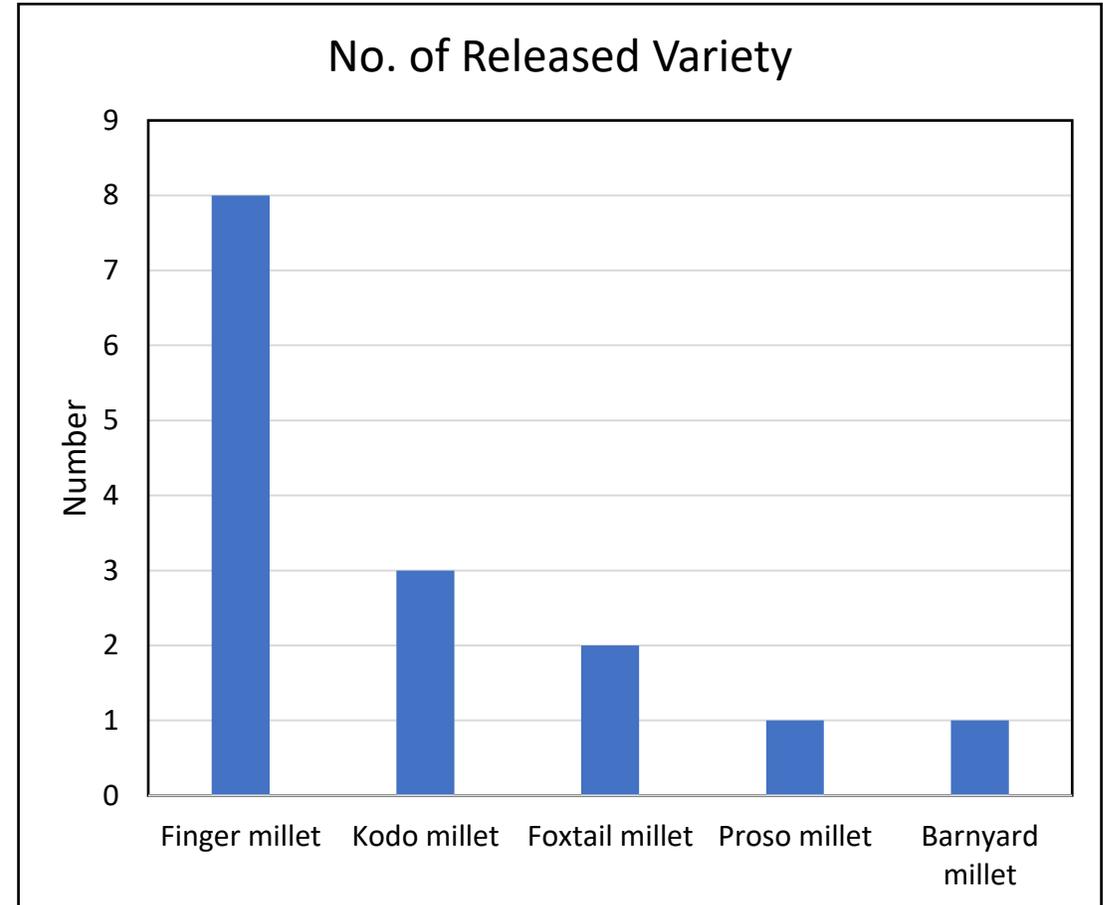
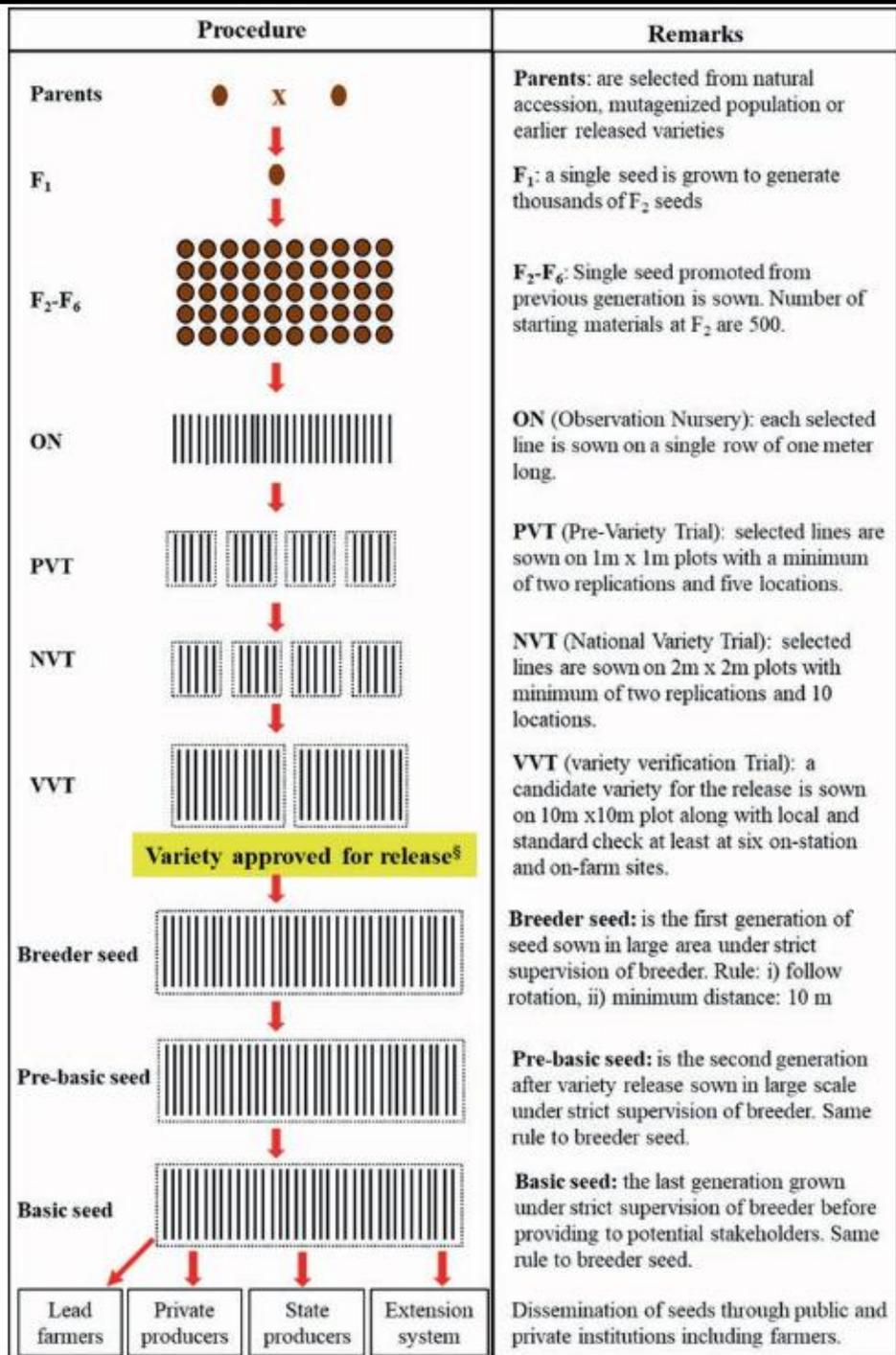
Ragupathy , S. et al., (2016)

Table 1 continued

Introduced Siru varagu <i>Paspalum scrobiculatum</i> (CBD2012EGRN56)	Powder is not dense, grains are small, follows a 3 months duration and low nutritious , resistance to weed "Malla" (Striga root parasite)
Perum varagu <i>Paspalum scrobiculatum</i> (CBD2012EGRN84)	Powder is dense, grains are large, 6 months duration, straw and grains are profitable.
Karum varagu <i>Paspalum scrobiculatum</i> (CBD2012SN41)	Grain is husk dark, powder dense, large and stem is short.
Senthavaragu <i>Paspalum scrobiculatum</i> (CBD2012SN43)	Straw is pinkish brown, palatable and is resistant to weed "Malla" (Striga root parasite)
Sadai thina <i>Setaria italica</i> (CBD2012EGRN73)	Germination point is black. Nutritious and low yield and taste good
Nattu thina <i>Setaria italica</i> (CBD2012EGRN74)	Germination point is white. Nutritious, high yield and taste is medium.
Palanthina <i>Setaria italica</i> (CBD2012SN15)	Grains white, culturally preferred as food, stem palatable, low yield.
Senthina <i>Setaria italica</i> (CBD2012SS26)	Grain husk red, grains can be stored for a longer time than other "thina". Stem stout, withstand the rain and wind blow.
Karumthina <i>Setaria italica</i> (CBD2012SS24)	Grain husk black, grains can be stored for a longer time than other "thina"; more yield. Stem stout, withstand the rain and wind blow

Breeding traits

Crop	Trait focus
Finger millet	Blast resistance, drought and salinity tolerance, machine harvestable, non-lodging, and bold grain size
Foxtail millet	Blast and sheath blight resistance, non-lodging, bold grain size, and strong culm for mechanical harvesting
Proso millet	Shoot fly and smut resistance, non-shattering, and non-lodging
Little millet	Shoot fly resistance, non-lodging, and bold grain size
Kodo millet	Shoot fly, head smut and sheath blight resistance, non-lodging, nutrient-response and drought recovery
Barnyard millet	Grain smut, sheath blight and shoot fly resistance, bold grain size, and non-shattering
Teff	Drought tolerance and lodging resistance, desirable grain quality, non-shattering, and bold grain size
Fonio	Non-shattering, non-lodging, early maturity, and bold grain size
Job's tears	Non-lodging, smut and leaf spot resistance



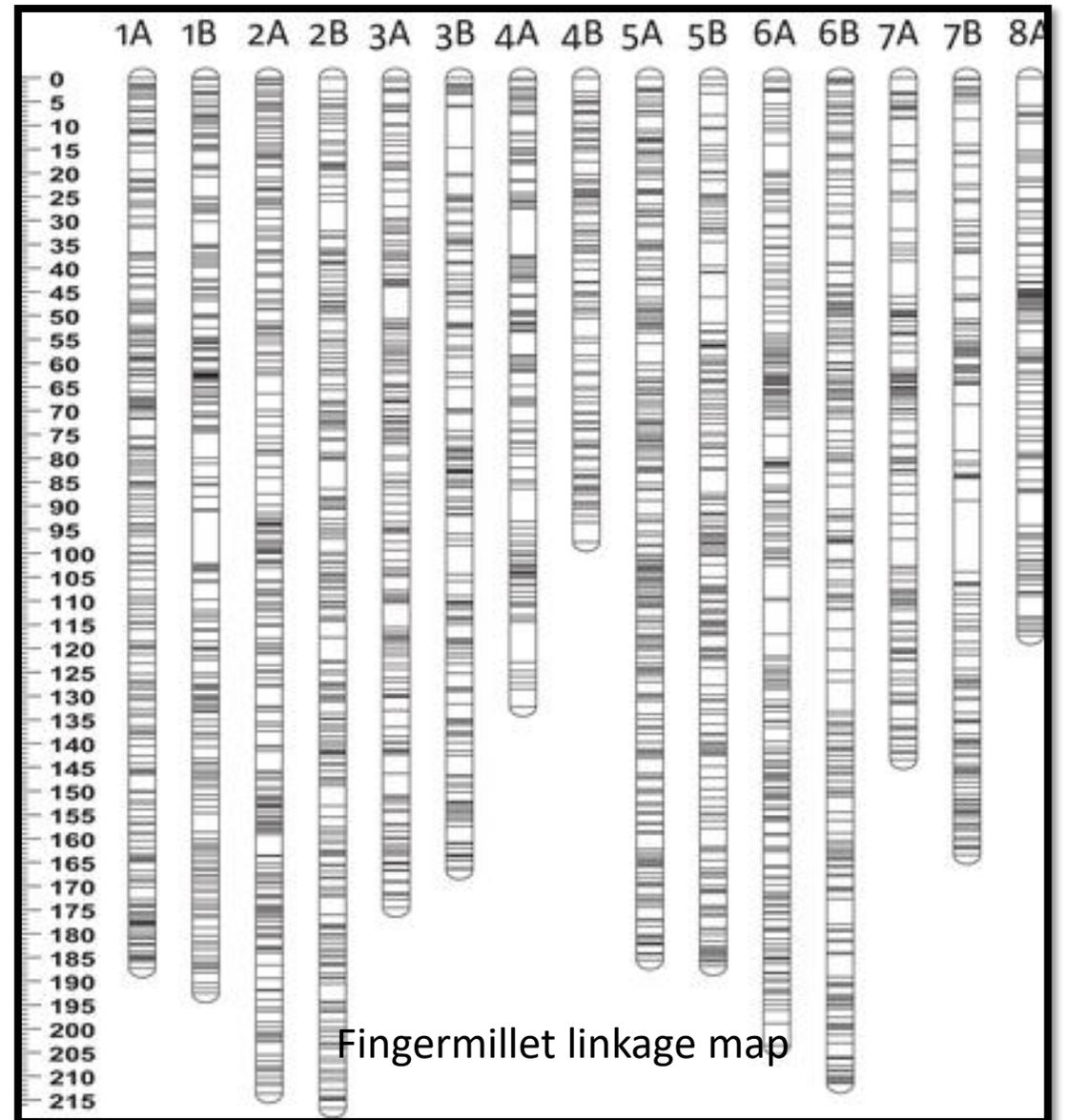
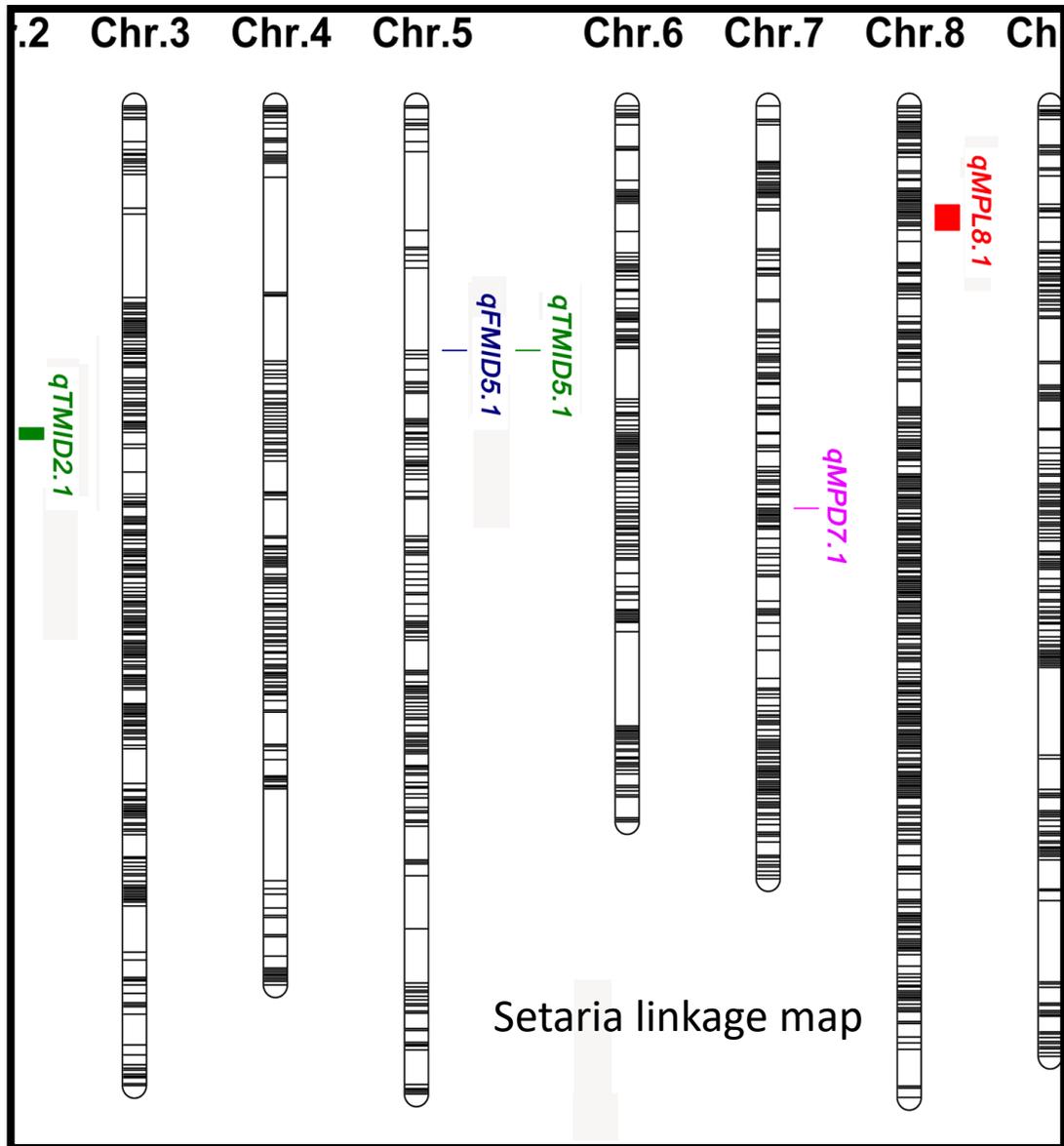
Finger millet

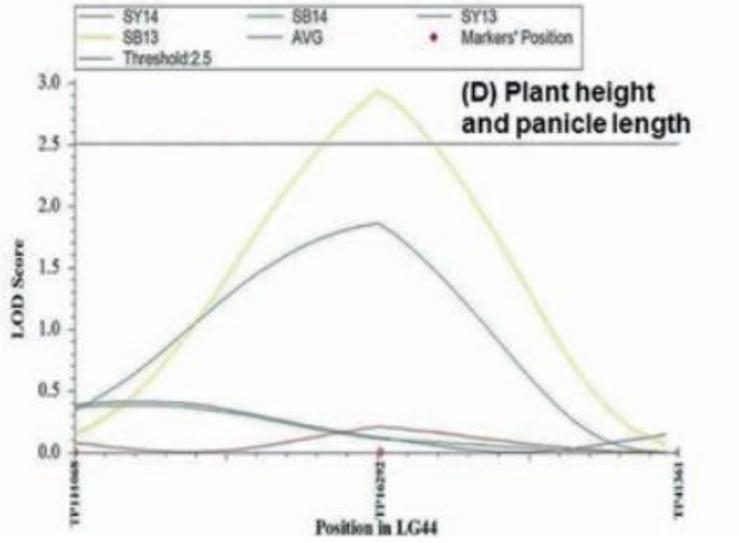
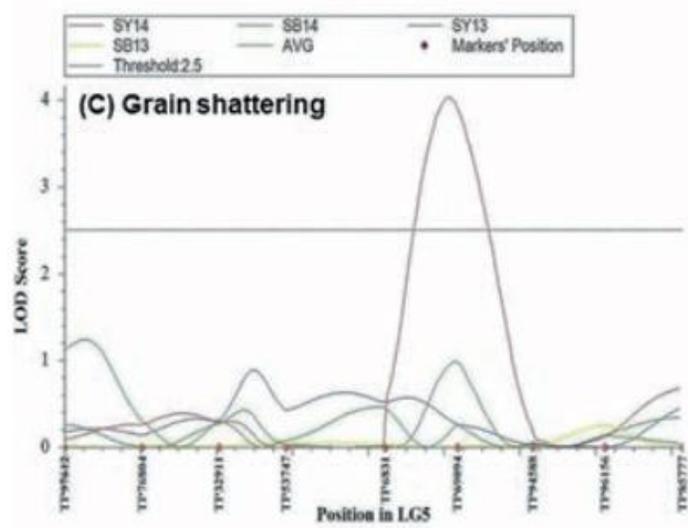
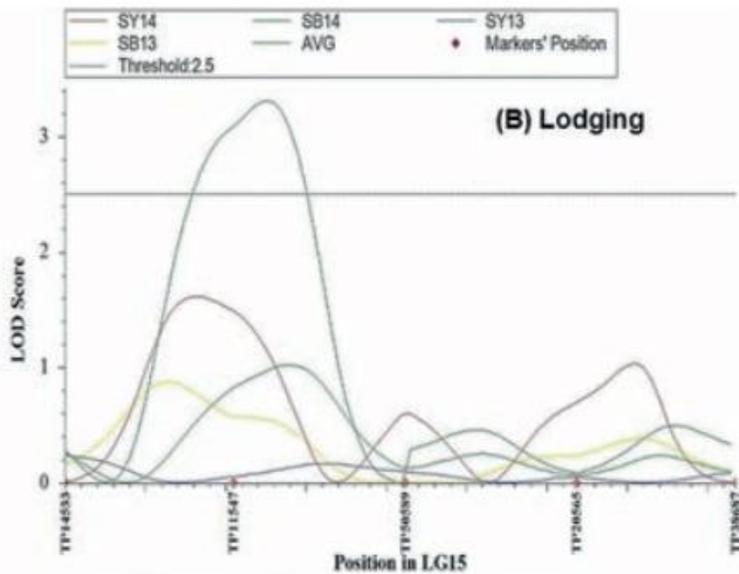
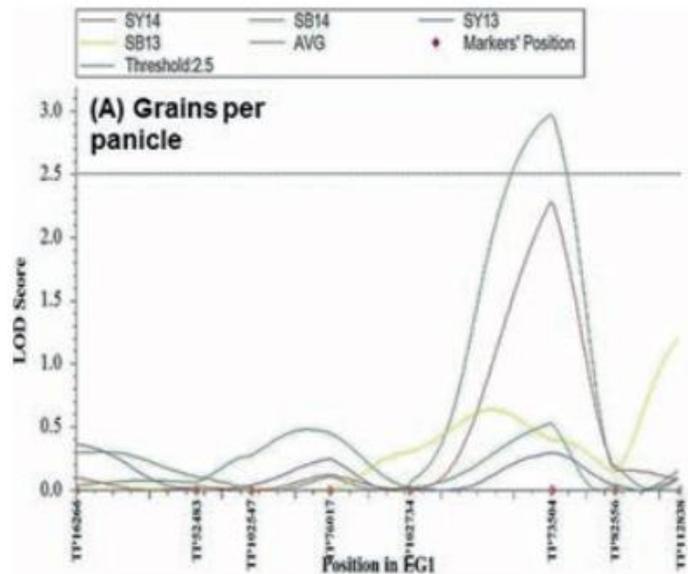
- A crop of poor people
- Anti-oxidant and anti-aging properties
- Anti-carcinogenic properties
- Anti-diabetogenic properties
- Prevention of gastro-intestinal disorder and malnutrition
- Cardio-protective and anti-hyperlipidemic properties
- Prevention of osteoporosis and other bone ailments



Genomic sequence resources

Crop	Scientific name	Genotype	Genome size	Number of genes	Sequence type
Foxtail millet	<i>Setaria italica</i>	Yugu1	510 Mb	24,000– 29,000	Reference genome
	<i>S. italica</i>	Zhang gu	423 Mb	38,801	Draft genome
Finger millet	<i>Elusine coracana</i>	ML-365	1196 Mb	85,243	Draft genome
		PR202	1500 Mb	62,348	Draft genome
Proso millet	<i>Panicum miliaceum</i>	Acc# 00000390	923 Mb	55,930	Draft genome
	<i>P. miliaceum</i>	Longmi4	887.8 Mb	63,671	Draft genome
Teff	<i>Eragrostis tef</i>	Tsedey DZ-Cr-37	672 Mb	28,113	Draft genome

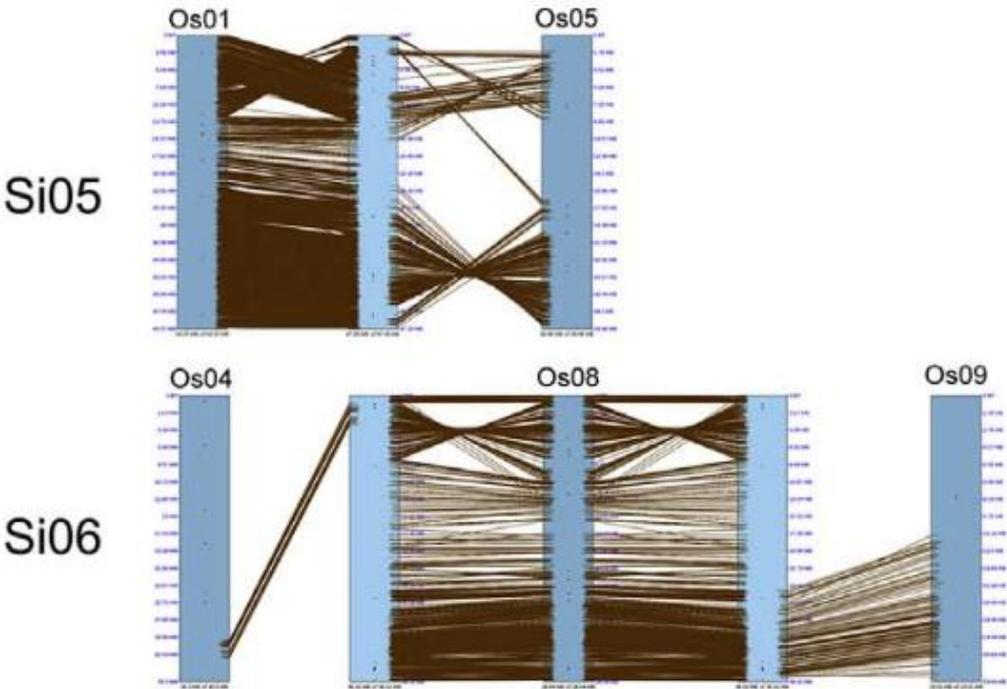
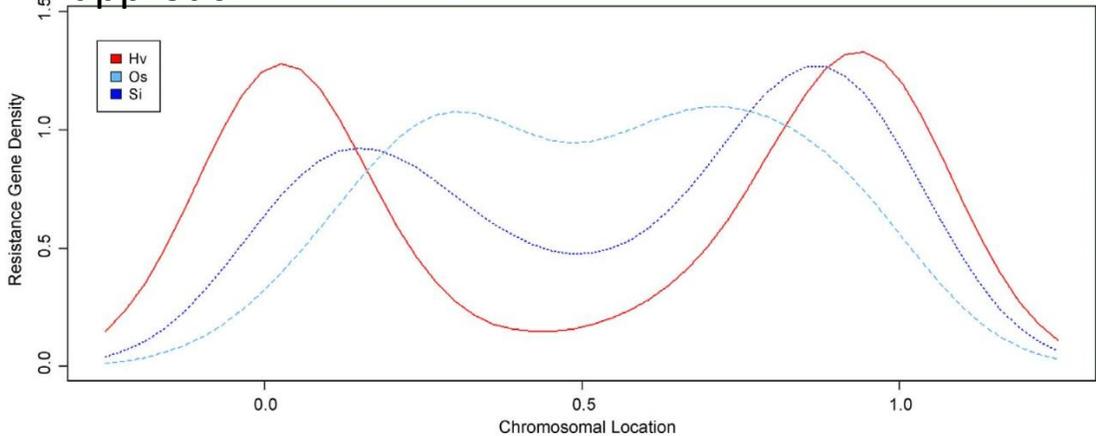




Nucleotide-binding site Leucine-rich repeat (NBS-LRR) in Foxtail millet

Three species compared were barley, rice and foxtail millet

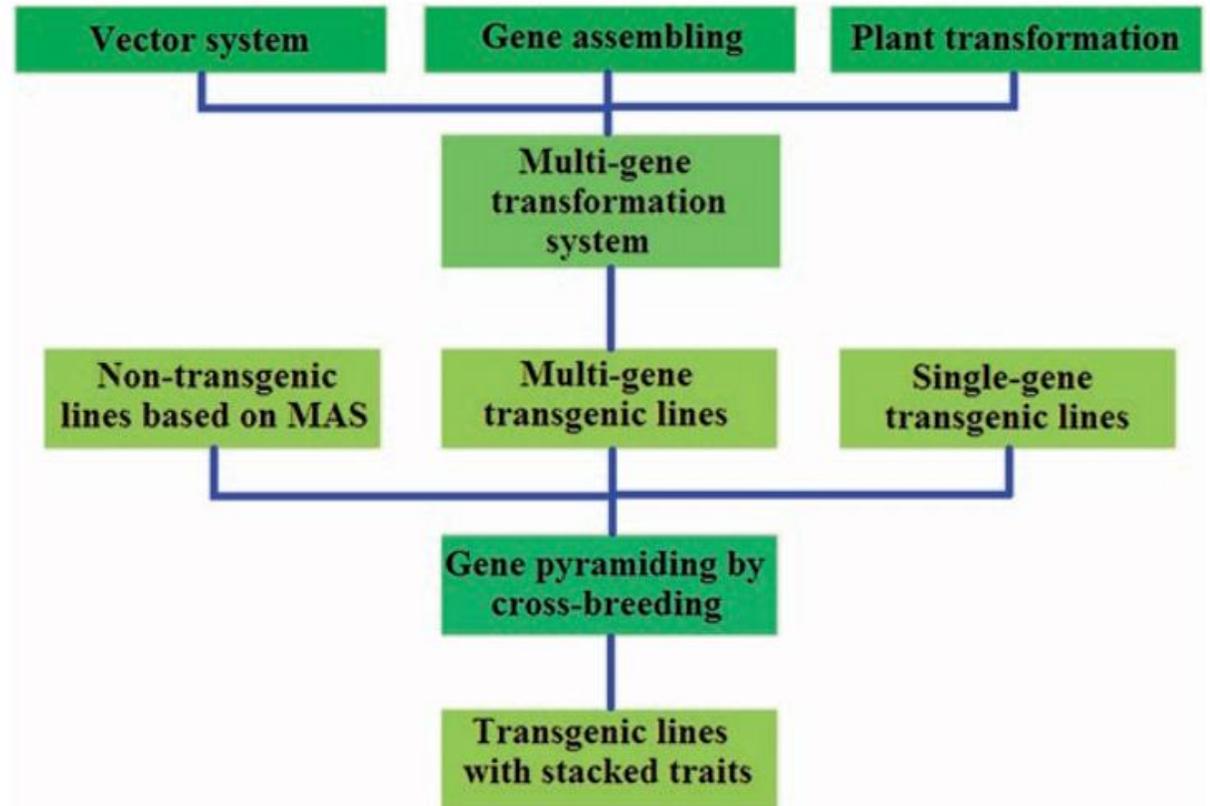
Approach adopted was maximum likelihood approach



Andersen and Nepal (2017)

Genetic transformation

- Finger millet: *Agrobacterium*-mediated transformation resulted 44.4% success rate using embryogenic seeds
- Foxtail millet: 90.7% transformation rate using callus
- Fonio millet: About 2.7% using callus.



Bioinformatics

Methods →

↓ Tools

Transcriptomics

Array Express

Array Track

Dragon

Proteomics

Genemania

STRING

Osprey

Metabolomics

KEGG

GOEAST

GOstat

Phenomics

Garnet

Phenomenet

Phenomeblast

Summary

- Minor crops are nutritious, we should diversify our food system
- Excellent genetic and genomic resources available for millets
- Available resources can be exploited for further improvement
- We can expand the international collaboration if necessary

Questions?