The Story of Millets

Karnataka State Department of Agriculture
in association with
ICAR-Indian Institute of Millets Research
Hyderabad

Sorghum

Pearl Millet

Finger Millet

Foxtail Millet

Kodo Millet

Barnyard Millet

Proso Millet

Little Millet

The Story of Millets

Millets were the first crops
Millets are the future crops

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Foreword

Millets are the ancient crops of the mankind and are important for rainfed agriculture. They are nutritionally rich and provide number of health benefits to the consumers. With Karnataka being a leading state in millets production and promotion, the government is keen on supporting the farmers and consumers to realize the full potential of these crops.

On the occasion of International Organics and Millets Fair, 2018, we are planning before you a story on millets to provide a complete historic global perspective of journey of millets, their health benefits, utilization, current status and future prospects, in association with our knowledge partner ICAR - Indian Institute of Millets Research, with specific inputs from the University of Agricultural Sciences, Bengaluru. I commend the efforts of the authors in putting together the parts of the story and shaping it up for a general as well as technically inclined reader.

I hope this book will be useful to readers to know more about millets and will find reasons to use them beneficially, complementing our mission of promoting millets. It will also be useful for general readers to understand millets from a holistic perspective.

(G Satish)

Preface

In the recent times the millets have become important owing to their good nutritional values, documented health benefits, versatile environmental adaptation, sustainability in low input agriculture and organic cultivation amenability. This publication is an attempt to bring together the historical and the present status of all millets in the world as well as in India. This would give a cursory impression of the way millets have been adopted and utilized by different societies in the course of history.

This book summarizes the broad information on millets, their nutritional and health benefits, origin and domestication, historical perspective, utilization, R&D efforts, present status and the importance being given by policy makers for promoting millets for sustainable agriculture and healthy society. While the book is intended for general audience, some technical details are also included for the readers who may need more information. Detailed references are not included as this compilation is only for the purpose of awareness and education. However, every attempt has been made to ensure that all the information have been complied from credible sources.

The authors are grateful to the publisher Karnataka State Department of Agriculture for coming up with the idea of such a publication on the occasion of International Organic and Millets Fair wherein clients from across different sections of society would be participating. We also place on record the support and encouragement received from Indian Council of Agricultural Research for our efforts on promotion of millets.

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Authors

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Understanding millets

Millets are group of small grained cereal food crops which are highly nutritious and are grown under marginal/low fertile soils with very low inputs such as fertilizers and pesticides. These crops largely contribute to food and nutritional security of the country. Most of millet crops are native of India and are popularly known as Nutri-cereals as they provide most of the nutrients required for normal functioning of human body. Millets are rain fed crops and are grown in regions with low rainfall and thus resume greater importance for sustained agriculture and food security. Based on area grown and its grain size the millets are classified as major millet and minor millets. The major millets include sorghum (jowar) and pearl millet (bajra). The finger millet (ragi/mandua), foxtail millet (kangni/Italian millet), little millet (kutki), kodo millet, barnyard millet (sawan/jhangora), proso millet (cheena/common millet), and brown top millet (korale) are categorized under minor millets. In certain countries of Africa, other millets such as fonio and tef are grown. Millets were the first crops to be domesticated by the mankind in Asia and Africa which later on spread across the globe as critical food sources to the evolving civilizations. All these millets have shorter growing duration complete their life cycle in 2-4 months, fit wide range of cropping systems and also adapt themselves to the changing environmental conditions especially during vagaries of monsoon.

Millets are major energy source and staple foods for people living in the dry and arid regions of the world. The stover after harvest of grains is a source of nutritive fodder to animals apart from its industrial use as bird feed, brewing, potable alchohol *etc.* Millets had been the lifeline of dry regions of Asia and Africa for food and fodder.

Most of the millets are *kharif* season crops (sown during May-June) and come to maturity during September to October. Most of these crops give good yields during *rabi* season (October-March) and summer season (January-April). Millets require very less water as compared to rice and wheat and considered drought tolerant crops. These crops are majorly grown in regions receiving less than 450 mm rainfall (compared to about 700 mm minimum for maize). About 50% of sorghum and 80% of millet production is used for human consumption while the rest is used for poultry feed, potable alchohal and other industrial purposes.

Millets are sometimes referred to as famine crops since they are the only crops that assure yields in famine situations. Earlier, these crops were also called as orphan crops since they are the last option for cultivation as they have less demand in the

market and profits earned are also lower than other crops. However, these neglected crops are important by virtue of their contribution to the means of livelihood, food and nutritional security of the poor in various parts of the world and they diversify our food basket. Before getting to more about the utility of millets and the story of their domestication, let us know briefly about each of the common millets grown today.

Millets were the oldest foods known to humans but their importance and cultivation reduced due to large scale cultivation of rice and wheat because of urbanization and industrialization. With diabetes, hypertension and cardiovascular disease becoming more prevalent, as gifts of newly acquired life-styles and food habits, millets have returned as a viable option to live healthy life and can reduce the incidence of these lifestyle diseases. Millets have many nutritional, nutraceutical and health promoting properties especially the high fibre content, nature of starch has major role in reducing the risk of diabetes other related diseases. Indeed millets act as a prebiotic feeding micro-flora in our inner ecosystem. Millet will hydrate our colon to keep us from being constipated. The high levels of tryptophan in millet produce serotonin, which is calming to our moods. Niacin in millet can help lower cholesterol. Millet consumption decreases triglycerides and C-reactive protein, thereby preventing cardiovascular disease. All millet varieties show high antioxidant activity. Millet is gluten free and non-allergenic. The beneficial effects of millets on human health are reported in many literatures and are available online.

Sorghum field at seed set stage *Inset: sorghum ear head and threshed grains*

Sorghum, (also known as Jowar) is the world's fifth major cereal food crop in terms of production and acreage after rice, wheat, maize and barley. In India, the sorghum grains are used mainly for food while the stover after harvest of grains is highly valuable as nutritive fodder to animals. The grains are also used for poultry feed and has other industrial uses such as potable alcohol production. Sorghum scientifically known as C4 plant, is one of the most energy efficient crops in use of solar energy and water to produce food and biomass. The crop has inherent drought tolerant nature and can be grown under wide range of environmental conditions. In the semi-arid regions sorghum is a dual-purpose crop, as both grain and stover are highly valued for human and animal consumption, respectively. Certain varieties of sorghum are exclusively grown for nutritional fodder especially in North Indian States and is highly accepted fodder crop over other cereal fodders. In India, it is grown extensively in north-western, western and central India,

Southern peninsula and in pockets of north-eastern states, with maximum acreage in Maharashtra and Karnataka. Sorghum has a strong stem and grows to a height of 2 to 8 feet, sometimes reaching as high as 15 feet. Stem of certain varieties are juicy and sweet like sugarcane and is presently one of the growing avenue for its use for bioethanol production. The leaves are about 2.5 feet long and 5 cm breadth. The tiny flowers are produced in panicles that range from loose to dense; each flower cluster bears 800–3,000 kernels. The seeds vary widely among different types in colour, shape, and size. Based on its use, the sorghum is classified as grain sorghums, forage sorghums (for pasture and hay), sweet sorghums (for syrups and biofuel), and Broomcorn.

Due to sorghum's wide uses and adaptation, "sorghum is one of the really indispensable crops" required for the survival of humankind. This crop in grown in nearly 100 countries, and contributes to more than 60% of millets produced globally.

Pearl millet is commonly known as bajra is the sixth major cereal in terms of area and production and has the highest drought tolerance potential of all millets. Pearl millet is the most widely cultivated cereal in India after rice and wheat. It is grown on more than 9.3 million ha with current grain production of 9.5 m tonnes and productivity of 1044 kg/ha. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in country. Pearl millet can easily provide economical grain yield (600 – 700 kg/ha) under marginal and low management conditions with the additional ability to produce a grain yield of 4-5 t/ha when hybrids of 80-85 days maturity are grown in summer season crop under irrigated and high fertility

conditions. It is a tall, erect plant and grows from 6-15 feet in height. The plant produces an inflorescence with a dense spike-like panicle, which is brownish in colour. With ovoid grains of 3 – 4 mm length, pearl millet has the largest kernels of all kinds of millets, except sorghum, which may be nearly white, pale yellow, brown, grey, slate blue or purple in colour. Pearl millet is the most widely cultivated cereal in India after rice and wheat. It is grown on more than 9.3 m ha with current grain production of 9.5 m tonnes and productivity of 1044 kg/ha. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in country. Pearl millet can easily provide economical grain yield (600 – 700 kg/ha) under marginal and low management conditions with the additional ability to produce a grain yield of 4-5 t/ha when hybrids of 80-85 days maturity are grown in summer season

Pearl millet field at seed set stage *I nset: Pearl millet ear heads and threshed grains*

crop under irrigated and high fertility conditions. Pearl Millet commonly known as Bajra in India is rich in essential compounds like protein, fibre, phosphorous, magnesium and iron. Due to its rich composition of minerals and proteins, pearl Millet has many health benefitting properties.

Pearl millet is the most drought and heat tolerant of all cereals being associated with cultivation in high temperatures, light soils and semi-arid growing conditions. Nevertheless, it responds spectacularly to good management with exceptional potential for grain as well as fodder production.

Finger millet is an important primary food especially for the rural populations of Southern India and East & Central Africa. Finger millet or ragi can be grown under wide range of adaptation ie from sea level to hilly regions of Himalayas but thrives best under well drained, loamy type of soils. About 60% of finger millet is produced by the state of Karnataka which is about 34% of global production. Finger millet is a dwarf, highly tillering plant with characteristic finger like terminal inflorescences. The height of a mature plant ranges from 30-150 cm and the seeds are very small like mustard and are light brown, or dark brown or white in colour. The crop matures in 3-5 months depending on the variety and growing conditions. The grains of finger millet are rich in quality protein having high amounts of tryptophan, cystine and methionine, fibre (10-15% dietary fibre), phytochemicals, calcium and other minerals. The crop is adapted to fairly reliable rainfall conditions and has an extensive but shallow root system. The grain is very nutritious, and has excellent malting properties. Finger millet is comparatively resistant to storage insect pests which make the crop an important source of food during famine as the grains can be stored as long as 50 years without much loss due to deterioration.

Finger millet has the highest productivity of (1640kg/ha) among the millets in India, and is frequently grown both dry and irrigated on lands where moisture is insufficient for rice. The grain have excellent malting properties and is widely known for its use as weaning foods.

Finger millet field at seed set stage *Inset: Finger millet ear head and threshed grains*

Foxtail millet is the third largest crop among the millets, cultivated for food in semi-arid tropics of Asia and as forage in Europe, North America, Australia, and North Africa. Foxtail or Italian millet may well have unrealized potential for grain production. It forms a slender, erect, leafy stem varying in height from 1-5 feet. Seeds are borne in a spike-like, compressed panicle resembling yellow foxtail, green foxtail, or giant foxtail. The grains are very similar to paddy rice in grain structure. They contain an outer husk, which needs to be removed in order to be used. The Chinese claim exceptionally high yields sometimes exceeding 11,000 kg per ha. It is drought - resistant, grows at higher elevations (up to 600 feet) and is frequently sown as an alternate crop with sorghum on black cotton soils when rainfall is deficient. It also grows well on loamy or alluvial and clayey soils. China grows most of the world's crop, but some Italian millet is grown in India, Japan, and Russia. In the USA. it is largely sown for fodder.

Generally grown in semi-arid regions, foxtail millet has a low water requirement and successful almost entirely to its short growing season. It matures in 65-70 days. Foxtail millet can be planted when it is too late to plant most other crops.

Foxtail millet field at seed set stage *Inset: Foxtail millet ear head and threshed grains*

Proso millet is a short-season crop cultivated in drier regions of Asia, Africa, Europe, Australia, and North America. Also called common or broom corn millet is a relatively short-duration emergency or quick-season irrigated crop with low moisture requirements. It is a relatively low-demanding crop with no known diseases. Proso millet is well suited for many soil types and climate conditions. Proso millet is highly drought-resistant, which makes it of interest to regions with low water availability and longer periods without rain. Compared to all millets proso is a short season crop, reaching maturity in 60 to 75 days after planting. It is most frequently grown as a late seeded summer crop. Proso millet grows three to four feet tall. Its compact panicle droops at the top like an old broom, hence the name broom corn. Its round seeds are about 1/8 inch wide and covered by a smooth, glossy hull Seeds may be cream, yellow, orange-red, or brown in colour. The grain after hulling makes a nutritious and palatable cereal for unleavened bread or cooked. This millet was grown in Russia, China, the Balkan countries and Northern India in historical times, being later replaced in most areas by rice and other cereals.

Barnyard millet is predominantly cultivated in India, China, Japan, and Korea for food as well as fodder. Japanese and Indian species of this millet are vigorous and have a wide adaptation in terms of soil and moisture requirements.

Proso millet field at seed set stage *Inset: Proso millet ear head and threshed grains*

Barnyard millet field at flowering stage *Inset: Barnyard millet ear head and threshed grains*

They grow well in different seasons and at higher elevations, but require three to four months for maturation. It is cultivated on marginal lands where rice and other crops will not grow well. Barnyard millet is an erect plant 60-130 cm tall and spikelets are brownish to purple. It is grown for both grain and fodder in India especially in the hilly tracts of Uttarkhand, Eastern Asia and parts of Africa, and in the Eastern USA it has been a valuable forage crop. A relative, Australian millet (Echinocloa decompositum), is used by the aborigines of that continent as a cereal grain.

Kodo millet field at flowering stage *Inset: kodo millet ear heads and threshed grains*

Kodo millet is native to the tropical and sub-tropical regions of South America and domesticated in India 3,000 years ago. Kodo millet is extensively grown on the poorest of soils throughout India but is probably not cultivated to any extent elsewhere. It is reputed to be extremely hardy, drought resistant and grows on stony or gravelly soils which would not support other crops. It is relatively long in duration requiring four to six months to mature compared with two to four months for the other millets. Short duration varieties have now been developed. Kodo is an annual tufted grass that grows up to 90 cm high. The grain is enclosed in hard, corneous, persistent husks that are difficult to remove. The grain may vary in colour from light red to dark grey.

Little millet was domesticated in the Eastern Ghats of India occupying a major portion of diet amongst the tribal people and spread to Sri Lanka, Nepal, and Myanmar. Little millet appears related to proso but is generally shorter, has smaller panicles and seeds, and is grown on a limited scale voluntarily or with minimum care on poor lands. Little millet matures quickly and withstands both drought and water logging. Less genetic diversity occurs in the world collections of this species than appears among the other species and the grains are similar to that of rice. Perhaps very little of this species is grown outside of India.

Little millet field at seed set stage *Inset: Little millet ear head and threshed grains*

Brown top millet, a native of India, has relatively limited cultivation to the parts of Karnataka and Andhra Pradesh, though its occurrence as a weed is noted in all states of India. It is primarily used as a food crop in India. . It can be grown even in less fertile sandy loam soils and matures in 60-80 days and is the most inexpensive crop to grow and does not need weeding and has no serious pests and diseases. In the United States as much as 100,000 acres are grown annually chiefly in Georgia, Florida and Alabama for hay and pasture; while the seed provides feed for quail, doves and other game birds. As a fodder crop it is finer-stemmed and quicker-growing than pearl millet.

Tef is a high-elevation (up to 2700 meters) cereal confined largely to the highlands of Ethiopia and Eritrea. Tef is more like a grass, can be grown under a wide range of conditions, including situations not suitable for other cereals. It bears very tiny seeds which are highly nutritious, especially in protein content. The primary use of tef is for grinding into flour to make injera, the spongy fermented flat bread that is a staple food for most Ethiopians. This crop needs minimum tillage to cultivate, though productivity is less. A handful of teff is enough to sow a typical field, and it cooks quickly, using less fuel than other foods. Teff also thrives in both waterlogged soils and during droughts, making it a dependable staple wherever it's grown. It is known to be grown in more than 2 million hectares in Ethiopia.

Brown top millet field at seed set stage *Inset: Brown top millet ear heads and threshed grains*

Tef crop Clockwise from left - at flowering stage, ear head, threshed grains

The millet crops of the world

Millet	Scientific name	Common names	Major areas of production for grains	Use
Sorghum	*Sorghum bicolor*	Great millet, jowar, cholam, jola, jonna, durra, Egyptian millet, feterita, Guinea corn, jwari, juwar, milo, shallu, gaoliang, kaoliang, kafir corn, dura, dari, mtama, solam.	USA, Nigeria, Sudan, Mexico, Ethiopia, India, Argentina, China, Niger, Australia	Grown for food grain in Asia and Africa, for fodder in Americas
Pearl millet	*Penn-isetum glaucum*	Bajra, cattail, bulrush, candlestick, sanyo, munga, seno	India, Western & Central Africa, Eastern & Southern Africa	Grown for food grain in Asia and Africa, for fodder in Americas
Finger millet	*Eleusine coracana*	Ragi, African,bird's foot, rapoko, Hunsa, wimbi, bulo, telebun, koracan, kurakkan	India, Ethiopia, Nepal, Uganda, Malawi, Burundi, Sri Lanka, Rwanda	Grown for food grain and beer making in Asia and Africa

Foxtail millet	*Setaria italica*	Italian, German, Hungarian, Siberian, kangani, navane, thanahal	China, Myanmar, India, Eastern Europe	Grown for food grain and fodder
Proso millet	*Panicum milliaceum*	Common, hog, broom, samai, Russian, panivarigu, panic, maha meneri	Russia, USA, Ukraine, South Korea, Kazakhstan, France, Poland, Belarus, India, Iran	Grown for food grain and bird seed
Little millet	*Panicum sumatrense*	Blue panic, heen meneri	India	Grown for food grain
Kodo millet	*Paspalum scrobiculatum*	Varagu, bastard, ditch, naraka, water couch, Indian paspalum, creeping paspalum, amu	India	Grown for food grain
Barnyard millet	*Echinochola crus-galli*	Japanese, sanwa, sawan, Korean, kweichou	India, Japan, China, Malaysia	Grown for food grain
Tef	*Eragrostis tef*	Abyssinian lovegrass	Ethiopia, Eritrea, Australia	Grown for food grain, and fodder
Fonio	*Digitaria exilis*	Fundi, hungry rice, acha	West Africa, Sudan, Ethiopia, Nigeria, Niger, Togo, Senagal, Mali	Grown for food grain in Africa

Fonio is cultivated to a limited extent mostly in West Africa on intermediate elevations or plateaus having somewhat more favorable rainfall and heavier soil s than the surrounding savannah. Nowadays, fonio grows in farmers' fields over a vast area extending from Senegal to Chad. The nutritive quality of fonio grain is quite high from analysis of protein fractions. White fonio is called 'acha' or 'hungry rice '(*Digitaria exilis* Staph) and black one is called iburu (*Digitaria iburua*). This small grass, which reaches heights of 30 - 80 cm, is very robust and can resist periods of droughts and heavy rains and matures in 70-150 days, depending on the variety. The fonio proteins are rich in the essential amino acid methionine, unlike other cereals. Like other millets, fonio has several proven health benefits including in preventing and managing diabetes. Fonio has a short growing season and is well adjusted to harsh environments. The cereal has excellent culinary and nutritional properties. The only drawback is that the grains are tiny and difficult to peel, which makes processing a tedious job.

Fonio crop at flowering stage *Inset: fonio ear heads, threshed grains*

Millets are basically starchy grains and have potential for industrial level production of starches, dextrin and ethanol for food and allied applications. In most of the developed countries, millets find extensive usage as feed components for bird, cattle and pigs.

Millets are smart foods

In this era of explosion of availability of super foods, the millets have a unique standing. They are easy and friendly to cultivate, are nearly organic and have good nutritional content. Therefore the following attributes are aptly applied to millets.

a. **Good for the consumer:** they can help overcome some of the biggest nutritional and health problems (iron, zinc, folic acid, calcium, diabetes and more);

b. **Good for the planet:** they have a low water footprint, are able to survive in the hottest driest climates and will be important in coping with climate change, and more;

c. **Good for the farmer:** can increase yields up to 3 fold, have multiple uses (food, fodder, fuel), and are typically the last crop standing in times of drought being a good risk management strategy for farmers.

Millet production map of India

Source: *Sahaja Samrudha*

Millets are powerhouses of nutrition

With the advances in modern science, the nutritional characteristics of millets have gradually been discovered. Though it was incidental that millets were the first crops to be cultivated, they were also more nutritious. However, their goodness was not known till biochemical and food and health science studies were carried out in the modern times.

Nutritional insecurity is a major threat to the world's population that is highly dependent on cereals-based diet, deficient in micronutrients. Millets are nutritionally superior as their grains contain high amount of proteins, essential amino acids, minerals, and vitamins. Almost all the millets are used for human consumption in most of the developing countries, but their use has been primarily restricted to animal feed in developed countries. Millets are nutritionally comparable to major cereals for carbohydrates/ energy, and serve as good source of protein, micronutrients and phytochemicals. The millets contain 7-12% protein, 2-5% fat, 65-75% carbohydrates and 15-20% dietary fibre.

Millets possess unique nutritional characteristics specifically have complex carbohydrates, rich in dietary fibre as well as unique in phenolic compounds and phytochemicals having medicinal properties. Millets are natural source of iron, zinc, calcium and other nutrients that are essential for curbing the problem of malnutrition in India. They have higher content of niacin, B6 and folic acid, and calcium, iron, potassium, magnesium and zinc. Finger millet is the richest source of calcium (300-350 mg/100 g) and other small millets are good source of phosphorous and iron. Millets are easy to digest, contain a high amount of lecithin and are excellent for strengthening the nervous system.

Nutritional composition of millets

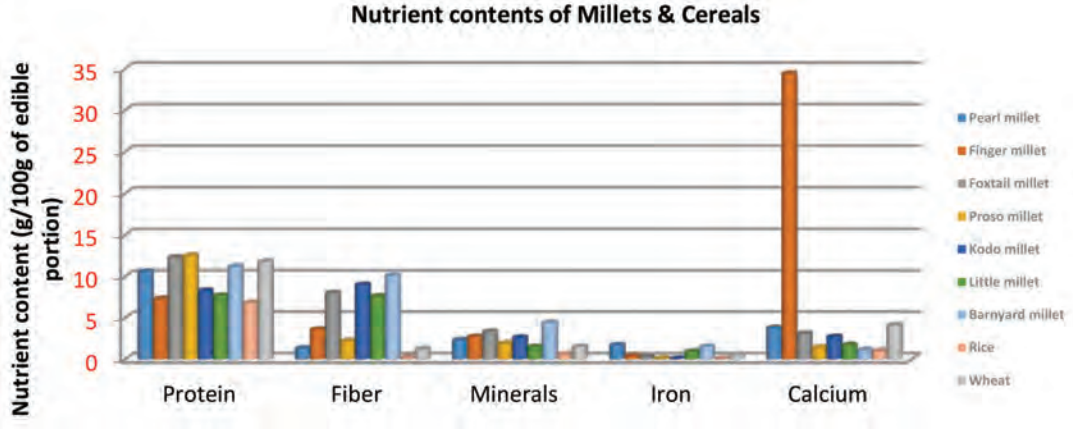
Grain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (Kcal)	Dietary fibre (g)	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	Thiamin (mg)	Ribo-flavin (mg)	Niacin (mg)	Folic acid (µg)
Sorghum	67.7	09.9	1.73	334	10.2	27.6	274	133	1.9	3.9	0.35	0.14	2.1	39.4
Pearl Millet	61.8	10.9	5.43	347	11.5	27.4	289	124	2.7	6.4	0.25	0.20	0.9	36.1
Finger millet	66.8	07.2	1.92	320	11.2	364.0	210	146	2.5	4.6	0.37	0.17	1.3	34.7
Kodo millet	66.2	08.9	2.55	331	06.4	15.3	101	122	1.6	2.3	0.29	0.20	1.5	39.5
Proso millet*	70.4	12.5	1.10	341	-	14.0	206	153	1.4	0.8	0.41	0.28	4.5	-

Foxtail millet*	60.1	12.3	4.30	331	-	31.0	188	81	2.4	2.8	0.59	0.11	3.2	15.0
Little millet	65.5	10.1	3.89	346	7.7	16.1	130	91	1.8	1.2	0.26	0.05	1.3	36.2
Barnyard millet*	65.5	06.2	2.20	307	-	20.0	280	82	3.0	5.0	0.33	0.10	4.2	-
Wheat flour	64.7	10.6	1.47	321	11.2	39.4	315	125	2.8	3.9	0.46	0.15	2.7	30.1
Rice	78.2	07.9	0.52	356	02.8	07.5	96	19	1.2	0.6	0.05	0.05	1.7	9.32
Ama-ranth seed	61	13.3	5.6	356	7.5	162.0	412	270	2.8	8.0	0.04	0.04	0.52	24.7
Quinoa	54	13.1	5.5	328	14.7	198.0	212	119	3.3	7.5	0.83	0.22	1.7	173

Source: *Indian Food Composition Tables, NIN – 2017; *Nutritive value of Indian Foods, NIN – 2007*

Small millets are more nutritious compared to fine cereals. They contain higher protein fat and fibre content. The dietary fibre, due to higher viscosity and water holding capacity, plays a key role in reduction of blood glucose level as well as insulin response. It also lowers the level of cholesterol and decreases the risk of bowel disorders. Dietary fibre components exert their beneficial effects mostly by way of their swelling properties, and by increasing transit time in the small intestine.

Millets contribute to antioxidant activity with phytates, polyphenols, tannins, anthocyanins, phytosterols and pinacosanols present in it having important role in aging and metabolic diseases. All millet grain and especially sorghum fractions possess high antioxidant activity *in vitro* relative to other cereals and fruits. Finger millet tops in antioxidant activity among common Indian foods.



Millets confer good health and protection against non-communicative diseases

Data on scientific evidences for nutritional and health benefit of millets are now available even as consumers are actually finding that millets are superior nutritious cereals beneficial for human health. Millets are recommended for well-being of infants, lactating mothers, elderly, and convalescents as suitable.

Millets contain slow releasing glucose, *i.e.,* low in glycemic index. This is very much important in fighting the global problem of diabetes. It is well recognized that, the incidence of diabetes mellitus and gastro-intestinal tract related disorders are minimal among the population using these grains as staple food. Its fibre content also helps to prevent constipation and may reduce the risk of developing bowel disorders including bowel, colon.

Properties of dietary fibre in millets and their health consequences

Function	Health consequences	Millet
Water absorbing and bulking property	Energy diluents to formulate low calorie diets	All Millets
Increased transit time of food in the gut	Reduced risk of inflammatory bowel disease.	Sorghum and Finger Millet
Bile acid and steroid binding	Hypocholestero-laemic activity and reducing the risk of cardiovascular diseases	Pearl Millet, Sorghum and Finger Millet
Retardation of carbohydrate absorption and impaired glucose tolerance	Management of certain type of diabetes	Sorghum, Pearl Millet and Finger Millet
Binding of toxins	As a detoxifying agent	Sorghum

Epidemiological studies have shown that diets rich in millets, including whole grains are protective against the non-communicable diseases like diabetes, cancer and cardiovascular diseases, due to protective effects of health promoting phytonutrients. Millets are good for people who are gluten-intolerant.

Magnesium is a micronutrient used for bone mineralization, teeth maintenance, building up of proteins, enzyme activities, normal muscular contractions and transmission of nerve impulses. Sorghum is considered a good source of potassium and is practically devoid of sodium. Whole grains are good sources of magnesium, iron, zinc, and copper. Finger and tef millet are good source of dietary calcium. The percentage of available magnesium is higher in millet than in sorghum, and iron content is significant.

Major portion of sorghum protein is prolamin (kafirin) which has a unique feature of lowering digestibility upon cooking whereas, the millets have a better amino acid profile. Sorghum proteins upon cooking are significantly less digestible than other cereal proteins, which might be a health benefit for certain dietary groups. On the other hand, millets contain fewer cross-linked prolamins, which may be an additional factor contributing to higher digestibility of the millet proteins. Sorghum starch is gluten-free, making sorghum a good alternative to wheat flour for individuals suffering from celiac disease.

The Naked caryopsis of finger millet with brick red coloured seed coat is generally used in the form of whole meal in the traditional food preparations such as roti, muddle and ambali (thin porridge). Regular consumption of whole grain cereals and their products have shown in epidemiological studies that they can protect against risk of diabetes mellitus, gastrointestinal diseases and cardiovascular risks. The use of millets as whole grain makes the essential nutrients such as dietary fiber, minerals, phenolics and vitamins concentrated in the outer layer of the grain or the seed coat form the part of the food and offer their nutritional and health benefits .

Pearl millet has a free lipids content range of 5.6-7.1% and bound lipids range of 0.57-0.90%. The presence of good amounts of phospholipids consisting both lecithins and cephalins, also offer many health advantages. These compounds are having great role in general metabolism, being concentrated in brain are useful in brain function, behavioral disorders and stress. They help in regeneration of membranes and protect liver, lungs, kidneys, and gastrointestinal tract. These compounds are known to enhance the bioavailability of other nutrients and medicines.

The niacin content in pearl millet is higher than all other cereals whereas, finger millet proteins are unique because of the sulphur rich amino acid contents. Similar to cereal proteins, the millet proteins are poor sources of lysine, but they complement well with lysine-rich vegetable (leguminous) and animal proteins form nutritionally balanced composites of high biological value. Millets are therefore consumed as multi-grains to reap the collective health benefits of nutrients.

Fonio is in the same class of super foods as quinoa, tef, and chia seeds. The grain is gluten free and rich in number of amino acids, which are often absent in other major cereals. It's easily digestible, and some varieties are rich in protein. Fonio also has a low glycemic index, making it ideal for diabetics. Fonio is prized everywhere for its easy digestibility and low glycemic index. Fonio is rich in methionine and cystine, two amino acids that are essential for growth.

In Africa, fonio is often served to honored guests and to convalescents, diabetics, and of course people suffering from celiac disease and gluten intolerance.

Kodo millet is rich in B vitamins especially niacin, pyridoxine and folic acid as well as the minerals such as calcium, iron, potassium, magnesium and zinc. It is also rich in fiber and low in fat content. It contains a high amount of lecithin and is an excellent for strengthening the nervous system.

Pearl millet is also proven to effectively help in maintaining the blood sugar level constant in diabetes patients for a long period of time Pearl mill*et al*.o contains significant amounts of potential antioxidants like phenols, phenolic acids, and carotenoids. Finger millet based diets have shown lower glycemic response due to high fiber content and also alpha amylase inhibition properties which are known to reduce starch digestibility and absorption. All small millets have been proven excellent anti-hyperglycemic activity. Millet based foods also help to obtain better nutrition and as well as considered as preventive medicine for diabetes as they are also rich source of protein and other nutrients. Thus, millet consumption helps in the prevention and control of diabetes.

Proso millet contains the highest amount of proteins (12.5%). Barnyard millet is the richest source of crude fiber and iron. Barnyard millet grains possess other functional constituents' et al.. γ-amino butyric acid (GABA) and β-glucan, used as antioxidants and in reducing blood lipid levels.

Millets benefit diabetics

There are many dietary advice and options readily available for diabetics. Some have even provided advice on food groups down to grain type. Recently, millets are receiving increasing spotlight in combating diabetes as a dietary option. The added benefit for millets is their potential positive contribution toward controlling the symptoms of diabetes. They are known to have higher SDS, mineral as well as leucine content that are positively attributed toward healthy diet for diabetics.

Millets and degenerative diseases

Diets high in fibre and antioxidants have been shown to have beneficial effect on serum lipid profile besides blood sugar. Some forms of cancer are also prevented by high fibre diets. Millets being high in fibre, antioxidants and complex carbohydrates are potential candidates for having beneficial effects against diseases like CVD, cancer and ageing in general. Millet consumption decreases triglycerides and C-reactive protein.

Sprouting millets makes more minerals bioavailable

Sprouted (malted) grains are commonly used as weaning foods for infants and as easily-digested foods for the elderly and infirm. Malting of finger millet increases the bio-accessibility of iron and manganese.

Finally, millets are healthy and nutritious foods, but not be understood as miracle foods or possess medicine-like values. Being staple foods, they can beneficially replace at least one to two portions of cereal intake of an average adult. Various traditional dishes can be made out of millets. Food market especially in urban areas is selling several modern day foods, ready to cook and ready to eat items, making available an array of options for consumers to embrace millets. Higher protein content of millets provides bulk of the daily recommended dose when consumed as staple food. Higher quantity of minerals in millets is helpful for body building and maintenance functions. Fibre-rich diet ensures easy and normal bowel movement. Comparable (to other cereals) portion of carbohydrates and their slower release ensures good control of blood sugar levels and facilitates delaying the next meal. Alkaline nature of millets based foods leads to healthy digestive system. Studies have revealed that populations with millets-based diets recorded lesser incidence of colon cancer. The millets are rich in anti-oxidants and thus support in managing stresses better and are good for our immunity system. Above all, millet-based diet, characterized by lower glycemic index, is excellent for preventing the incidence of life-style diseases, managing diabetes and reducing obesity.

Anti-nutrients in millets – challenges and solutions

Despite the well-documented health benefits of millets as excellent source of nutrients and minerals, they also contain some anti-nutrients (commonly called as phytochemicals) that negatively affect its nutrient values by reducing the digestibility of nutrients and mineral absorptions, some of which also confer 'slow glucose release' and 'anti-oxidant' properties. These anti-nutrients mainly include phytates, polyphenols, oxalic acids, tannins and digestive enzyme inhibitors *etc.* For example phytic acid (which is also present in other food grains in varying levels, including rice) binds with dietary minerals such as calcium, iron, magnesium and zinc and inhibits their absorption in our body. However, the negative impact of these anti-nutrients can be taken care by using common household food processing techniques like decortications, milling, soaking, malting, germination, fermentation, popping and cooking *etc.* These methods reduce the content of phytates, phenol, tannins and trypsin inhibitor activity, improve the digestibility of millets and also enhance the bioavailability of minerals.

Pearl millet has a characteristic in that the hulls and seeds contain small amounts of goiterogenic substances that limit uptake of iodine to the thyroid. In large amounts, these "thyroid function inhibitors" can cause goiter and some researchers feel this may explain, at least in part, the perplexing correlation between millet consumption and goiter incidence in some of the developing countries where millet constitutes a significant part of the diet. In many of these countries another contributing factor may be a lack of sufficient dietary iodine. However, it is recommended that those who have history of goiter and thyroid related issues should not adopt pearl millet-based diet.

The Origins of Millets

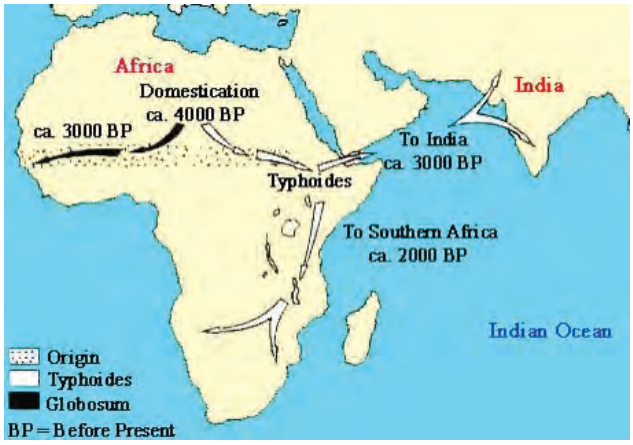
The millet crops originated in Asia and Africa, were domesticated by the local populations and spread to other regions of the world. Further domestication in other regions gave rise to secondary regions of diversity and adaptation and different use options. The origin of each millet is briefly discussed below.

Sorghum originated in north-eastern Africa, with domestication having taken place there around 5,000–8,000 years ago. The largest diversity of cultivated and wild sorghum is also found in this part of Africa. The secondary center of origin of sorghum is the Indian Subcontinent, with evidence for early cereal cultivation dating back about 4,500 years.

Panicle diversity in sorghum and pearl millet *Photo: ICRISAT*

The domestication of pearl millet occurred in northern–central Sahelian Africa around 4500 BC. Pearl millet continues to be a major cereal crop in West Africa. It is also widely grown in eastern and southern Africa and in semiarid to arid areas of India. It originated in the West Africa. The oldest archaeobotanical evidence of pearl millet cultivation was found in Mali and dated at around 2,500 BC.

Finger millet is a domesticated cereal of African origin which spread in prehistory to Asia, also sometimes referred to as korakan or ragi (a widespread local name in India) or dagusa (in Ethiopia). Although the wild progenitor species (*Eleusine africana* Kennedy-O'Byrne) is well established, location and the African native range of this species where it was cultivated remains unclear. One limited genetic study suggested that the hills of western Tanzania might be the region of origin, while many botanists have pointed to the Ethiopia highlands as a point of origin. Ecologically it is regarded as coming from an upland environment, and as a crop it is most commonly grown in hill zones, above 900 m. Nevertheless, it can be grown in the lowlands, to a limited extent in Africa and to a larger extent in India. In Asia upland races, which are especially widespread in the Himalayas from India to Nepal and southern China, appear to be a secondary adaptation.



Pearl millet was domesticated 4000 years ago and then spread to India 3000 years ago and to southern Africa 2000 years ago. India is considered as the secondary center of diversity

Finger millet is somewhat less hardy than other millets, preferring richer and wetter soils, but it has exceptional storage advantages. Finger millet grains are rarely attacked by pests or spoil in storage, and shelf life of up to a decade is commonly reported. Although it may survive with 500 mm of rainfall, it is generally grown on 800–1,000 mm. It is often the first crop in rotations of shifting cultivation or the second crop after rice, as it does not do as well on impoverished soils as other millets. While it can be made into porridges and flat breads, finger millet beers are traditional both in parts of Africa and Asia.

More than 100 species in *Setaria, S. macrostachya, S. pumila*, and foxtail millet (*S. italica*) cereals were domesticated by human beings. However, only **foxtail millet** became a worldwide crop, contributing greatly to the development of Chinese civilization and remaining as a staple cereal in arid and semi-arid regions. Green foxtail is the ancestor of cultivated foxtail millet and both can be regarded as the same species. This was domesticated in China more than 8000 years ago.

The proso millet or common millet is the true millet of the history and oldest of all in domestication. Most of the evidences ascribe it to a central or eastern Asiatic origin, since the diversity increases towards Mongolia, China and Eastern Asia.

Yellow River valley of China has been suggested to be the origin. Glutinous forms of proso millet developed from non-glutinous forms.

The origin of **little millet** crop is not well documented except for the probable Indian origin since it is endemic to India and has a name in all vernacular languages of India. This millet was cultivated or naturalized throughout India and Sri Lanka, and cultivated in neighbouring countries and no diversity and related wild species are found outside India, suggestive of Indian origin.

There is no much information on the origin of **barnyard millets**. General consensus is that these originated in central Asia; *Echinochola crus-galli* was domesticated in Japan, China and Korea whereas *Echinochloa frumentacea* was domesticated in India.

The kodo millet, also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass originates in tropical Africa, and it is estimated to have been domesticated in India 3000 years ago. *Paspalum scrobiculatum* var. *scrobiculatum* is grown in India as an important crop, while *Paspalum scrobiculatum* var. *commersonii* is the wild variety indigenous to Africa. Often it grows as a weed in rice fields. Many farmers do not mind it, as it can be harvested as an alternative crop if their primary crop fails.

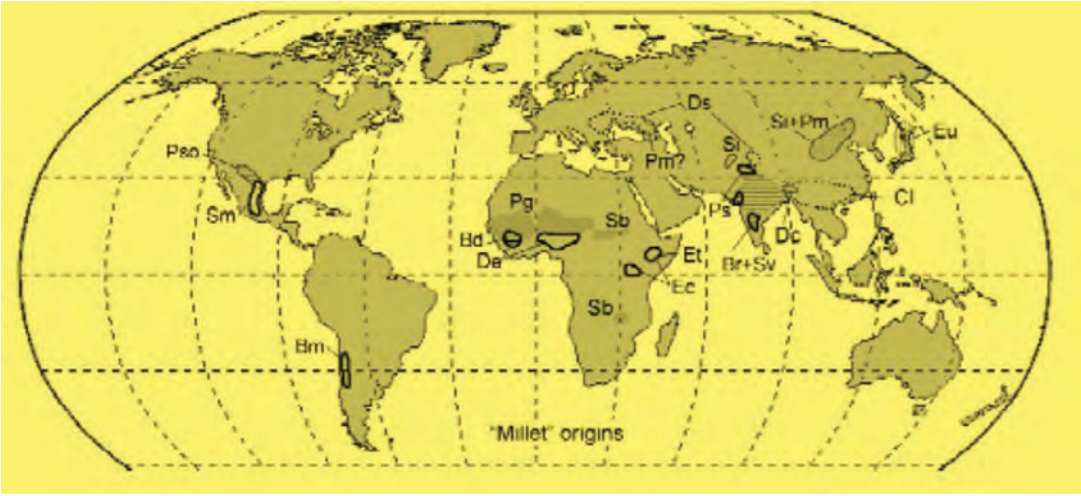


Fig 13 : The map of likely centres of origin for millets. Millets abbreviated: *Pso: Panicum sonoran; Sm: Setaria cf. macrostachya; Bm: Bromus mango; Bd: Brachiaria deflexa; De: Digitaria exilis; Pg: Pennisetum glaucum; Sb: Sorghum bicolor,* including Southern African zone where the race kafir may be an independent domesticate; *Ec: Eleusine coracana; Et: Eragrostis tef; Ds: Digitaria sanguinalis; Pm: Panicum miliaceum,* a separate Western origin remains unconfirmed; *Si: Setaria italica; Ps: Panicum sumatrense: Br: Brachiaria ramosa; Sv: Setaria verticillata; Dc: Digitaria cruciata; Cl: Coix lachrymal-jobi; Eu: Echinochloa crus-galli var. utilis.* The striped zone in India indicates the broader Indian millet zone within which several domestications remain to be better localized *(Paspalum scrobiculatum, Echinochloa colonum, Setaria pumila),* in addition to possible multiple domestications of *Brachiaria ramosa. Source Weber and Fuller (2007)*

Millets: taxonomy, common names, and regions of origin
[Weber and Fuller, 2007]

Species	Common name	Region of origin
Brachiaria ramosa (L.) Stapf. (syn. *Urochloa ramosa* (L.) R. D. Webster)	Browntop millet, pedda-sama	South India
Digitaria exilis (Kippist) Stapf.	Fonio, acha, fundi	West Africa
Digitaria iburua Stapf.	Black fonio, iburu, hungry rice	West Africa
Echinochloa colona (L.) Link ssp. *frumentacea* (Link) (= *E. frumentacea* Link).	Sawa millet	Peninsular India
Echinochloa crus-galli (L.) P. Beauv. (syn. *E. esculenta* (A. Braun)	Barnyard millet	Japan
Eleusine coracana (L.) Gaertn.	Finger millet, ragi	East African highlands
Eragrostis tef (Zucc.) Trotter	Tef	Ethiopian highlands
Panicum miliaceum L. ssp. *miliaceum*	Proso millet	China
Panicum sumatrense Roth. ex Roem. & Schult. Subsp. *sumatrense* (syn. *P. miliare* auct. pl.)	Little millet, samai	India, especially peninsula
Paspalum scrobiculatum L.	Kodo millet	India
Pennisetum glaucum (L.) R. Br (= *P. americium* (L))	Pearl millet	West African Savannah
Setaria italica (L.) P. Beauv ssp. *italica*	Foxtail millet	China
S. verticillata (L.) P. Beauv	Bristley foxtail millet	South India
Sorghum bicolor (L.) Moench ssp. *bicolor*	Sorghum, jowar	African Savannahs

The domestication of brown top millet probably occurred in South India, in the Deccan, and it spread during prehistory outward to other parts of India. Evidence suggests that this crop, along with other South Indian crops, developed from indigenous wild populations around the beginning of the third millennium BC.

Brown top millet, today, has a limited cultivation, largely confined to southern India. Domestic and wild/weedy forms of brown top millet are found in agricultural systems, often within the same field. It is used as both a human food crop and fodder. Outside of India, it is grown in some parts of the USA as a fodder crop, largely to provide food for game birds, and was introduced from India around 1915. Although its distribution is highly relict today, restricted to parts remote parts of Andhra Pradesh and Karnataka states in southern India, it appears to have been a major staple crop in the late prehistory of the wider region of the Deccan peninsula of India.

Journey of Millets

Millets were consumed as staple cereals and brewed from prehistoric times in Asia, Africa and Europe. They may have been among the first cultivated crops being grown in the "Hoe Age" preceding the "Plow Age". Before proper irrigation systems were invented, millet proved to be a very important staple food in African and Asian cultures, due to its drought resistant growth adaptations. Its importance continued until wheat and rice cultivation was perfected.

Proso millet is one of the oldest human foods and believed to be the first domesticated cereal grain. Though difficult to know exact origin, it's widely accepted that proso millet was domesticated and cultivated simultaneously in Asia and Africa over 7000 years ago during the Neolithic Era, and then spread throughout the world as a staple food. Millets have been a staple in arid areas of Asia and Africa for thousands of years.

In several parts of the world the earliest archaeological plant finds include millets, as is the case in regions of India, Mexico, China and Africa. Millets also formed important parts of the prehistoric diet in Indian, Chinese Neolithic and Korean Mumun societies. While in some regions millet cultivation follows the introduction of domesticates, in other regions it appears to be an independent process preceding the introduction of crops from other regions, as in South India and West Africa.

Proso and foxtail millet- Journey starts from China

Foxtail millet (*Setaria italica*) and common millet (or broomcorn/proso millet; *Panicum miliaceum*) were among the world's most important and ancient domesticated crops. They were staple foods in the semiarid regions of East Asia (China, Japan, Russia, India, and Korea) and even in the entire Eurasian continent before the popularity of rice and wheat, and are still important foods in these regions today.

Life in Stone Age China. 7000 years ago, the Yangshao lived on the Yellow River. Millet cultivation began

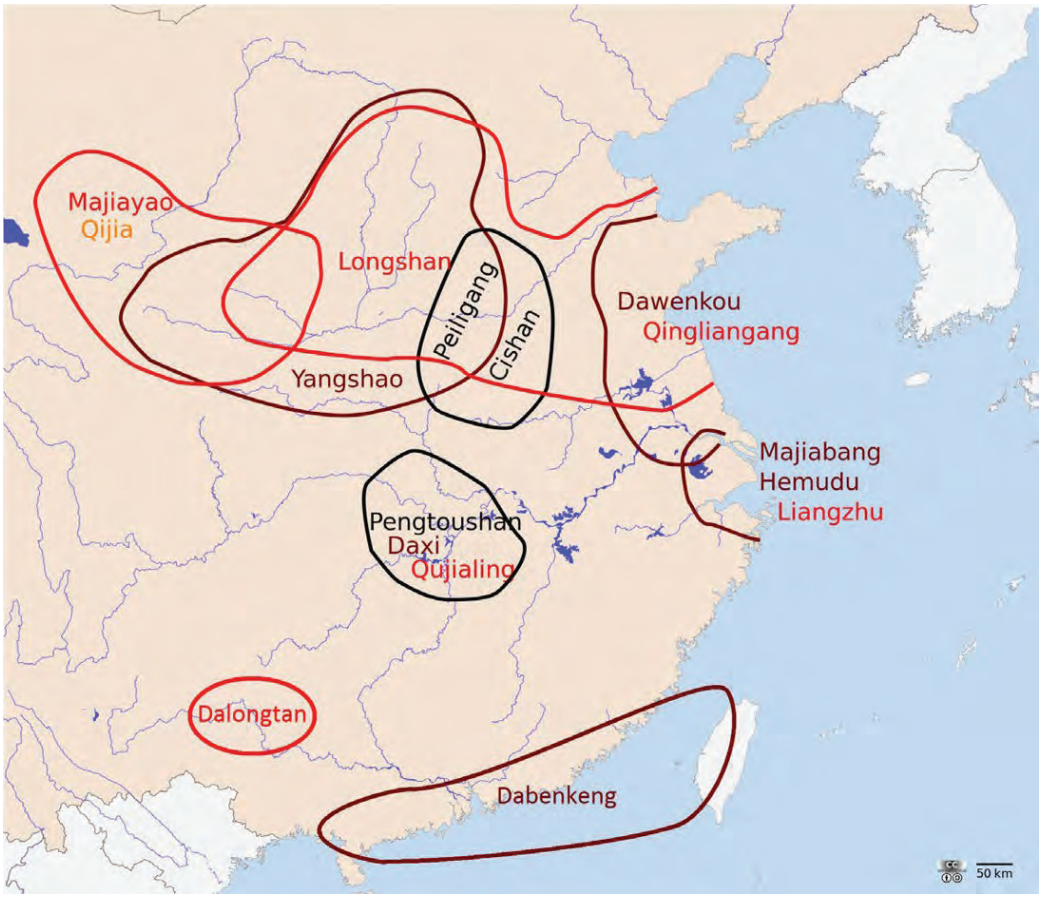
Illustration source: *Imgur/Diorama by Aaron Delehanty*

China's foodways began to take shape at the end of the last Ice Age. The glacial period was extremely cold and dry. As it broke, from 15,000 to 8000 BC, conditions rapidly ameliorated. By 10,000 BC, China was becoming warmer and wetter. Plant growth increased, making agricultural innovation more reasonable. As in the Near East at the same time, agriculture seems to have followed rapidly—stimulated, presumably, by increases in population, environmental productivity, trade, and communication.

Proso millet and foxtail millet were important crops beginning in the Early Neolithic of China which were the prevalent grains of China before rice. These millets were domesticated in northern China where they became the dominant traditional grain crops.

The world's oldest millet was found in the Yangshao area, which proceeded the Yangshao culture by about 5,000 years. Domestication of proso millet was as early as 8000 BC, whereas foxtail millet appears to have been exploited later at 6600 BC. Hunters and gatherers in early China probably ate millet. Millet seeds were ground into flour or meal using stone tools, then cooked in earthenware vessels as early as 8000BC.

Northern China was dry and cold, so it was a good place to grow millet. By around 5000 BC, people in north-central China were relying on millets as a staple food, and by about 3000 BC millet was a staple food all over northern China. The spread of proso millet to the more productive regions of the Yellow River and its tributaries provided the essential food surplus that later permitted the development of social complexity in the Chinese civilization. By 5000–6600 BC. proso millet was abundant in north China. By 4000 BC. it travelled to Eastern Europe, having probably spread across central Asia.



Neolithic cultures in China around 4000 BC. Yangshao culture along the upper and middle reaches of the Yellow River, where thousands of millet-farming villages were present

Source: *Lamassu Design / Wikimedia Commons*

The sign for millets is common in Chinese writing, where the signs for "millet" and "mouth" put together mean "good", and the signs for "millet" and "man" together mean "harvest" or "year". A 4,000-year-old well-preserved bowl containing well-preserved noodles made from foxtail millet and proso millet

was found at the Lajia archaeological site in China. Chinese legends attribute the domestication of foxtail millet to Shennong, the legendary Emperor of China. Millet meal cakes have also been discovered.

The earliest written record of millet, "Fan Shen Chih Shu" 2800 BC, gives detailed instructions for growing and storing the grain, and lists it as one of the five sacred Chinese crops along with soybeans, rice, wheat, and barley. Brewing was a major art form. Chinese *jiou*, translated "wine" but technically beer or ale, was invented long before the Shang dynasty. It was made from millet, and in the south (later, at least) it was made from rice. Shang wine vessels were of heroic proportions, and all sources agree that feasting went with heavy drinking.

Ancient Chinese feast – Song dynasty elegant party

Source: *wikimedia commons*

The history of plant domestication in China becomes brilliantly clear in the Zhou dynasty (ca. 1000 BC –221 BC). The "the Shi Jing", Book of Songs, a collection of Zhou folk and court poetry, from north China, reflects a world dependent on millets.

"The Descendant's stacks

Are high as cliffs, high as hills.

We shall need thousands of carts,

Shall need thousands of coffers

For broomcorn and foxtail millet, rice and spiked millet".

The Silk Road, the great trade route across central Asia, linked East and West, during Han dynasty (206 BC–220 AD) paved way for spectacular elaboration of wheat products in China. China, which fed on millet mush and boiled rice until Han, became a land of noodles, breads, filled and unfilled dumplings, and countless other complex wheat preparations. Gradually, during this period, wheat replaced millet as the staple of the north.

People have been farming proso millet in around 4000 BC, lake-dwelling Europeans were farming that millet, and by 3000 BC Sumerians in West Asia were also growing millet. By the 3rd millennium BC, proso millet cultivation appears to have spread to Kazakhstan and south through Thailand to India, but whether this crop was grown in these countries before this time is unclear. The Chinese book 'Classic of Shan Hai' (before 338 B.C.) puts on record that the Chinese people saw the black millet grown in the southern part of Australia by the aborigines.

From the Chinese and Mongolian centers of domestication, millet spread widely throughout East Asia, including high-altitude areas such as the Tibetan Plateau. By the end of the 1st century BC, the cultivation of proso millet had spread to the rest of Central Eurasia and to Eastern Europe. However, during the 2nd millennium BC, worldwide temperatures became cooler, and may have led to difficulties in millet cultivation. Evidence shows major shifts in proso millet farming on the Tibetan Plateau until its cultivation was abandoned in Eastern Tibet. Later, proso millet was largely replaced by wheat and barley on the Tibetan Plateau; however, it continued to be a popular crop in low-lying plains of northern China well after its introduction.

At farm museum near Beidahe, China. Dragon and pillar of foxtail millet and corn
Photo: *Barbara Partee*

Before the beginning of intensive farming of rice and wheat, millet was the main food crop especially in the northern China. Even during 7th Century, in the early Tang dynasty, *zu-yong diao* system of taxation and grain storage, millet was considered as a standard grain payment option for taxes.

Although regarded as poor men's food, rich Northerners preferring to eat wheaten breads or even rice, proso millet is still valued for its pleasant flavour and nutritious qualities even today, and despite competition from sorghum and maize its cultivation remained widespread in northern China until very recently.

China to Eurasia

Proso millet made its way from China to the Black Sea region of Europe by 6000 BC. The earliest millet in Europe was thought to be that found impressed in pottery at the Sokoltsy 2 site in Ukraine about 6,300 BC. Proso millet has been reportedly found in Neolithic sites in Georgia located at the crossroads of Western Asia and Eastern Europe (5-4th millennia BC), in Germany (near Leipzig, Hadersleben) by Linear Pottery

culture (5500–4900 BC). However, earliest evidence for proso millet cultivation in the Near East is a find in the ruins of Nimrud, Iraq dated to about 700 BC.

Some believe that Shepherds and herders probably carried the grain across Eurasia between 2,500 and 1,600 B.C. Domesticated millet from North China and Inner Mongolia travelled into Europe through a "hilly corridor" along the foothills of Eurasia. The cultivation of common millet as the earliest dry crop in East Asia has been attributed to its resistance to drought and this has been suggested to have aided its spread.

Millet was eventually mixed with other crops in emerging populations to create 'multi-crop' diversity, which extended growing seasons and provided our ancient ancestors with food security.

Early Egyptians learned how to grow millet in the arid Sahara around 3000 BC. The Moors in North Africa grew millet after discovering that it sprouted during the monsoon season and matured quickly. It was grown in southern A*rabi*a as well and in what was once called Gaul (France). People were farming millet in Israel by 600 BC. Greek historian Herodotus (485-420 BC) wrote that says that both the Persians and the Greeks were growing millet in his time The Romans called millet *milium* and made a polenta-like porridge called *puls*, that was similar to the Etruscans' porridge *pulmentum*. The explorer Marco Polo wrote about food under the rule of Genghis Khan, "They have no shortage because they mostly use rice, foxtail or proso millet, … they do not use bread, but simply boil these three sorts of grain". The Western European emperor Charlemagne ordered millet to be stored and used as a Lenten food. During the Middle Ages millet was the main staple grain in Europe and grown more widely than wheat.

In the Old Testament, Ezekiel 4:9, millet is mentioned as a grain for making bread. It was a staple of the Sumerians and treasured plant grown in the hanging gardens of Babylon. There is evidence that millet was grown during the Stone Age by lake dwellers in Switzerland and was eaten in Northern Europe at least since the Iron Age.

In Europe, the early cultivation of millets was in the Balkan Peninsula and Italy. The millets were widely grown in Europe during the middle ages being one of the principal foods of the poorer people of Rome and of Europe generally. The proso millet was known to the Romans in the time of Julius Caesar. This millet was described to thrive excellently in Gaul and was the best protection against famine. It was described by Pliny (23-79 A.D.) as constituting the principal food of the Sarmatians and Ethiopians knew of no other grain but millet and barley. In

the embassy of Theodosius to Attila (440-449 AD), beyond the Danube, millet was brought by the party as provisions. Johann Schultberger (1396-1427 A.D.) spoke of this millet as the only crop of Siberia and at Zepun on the Black Sea. In 16th century Solvenia, millet was a standard form of tax payment.

Millet in the Roman Diet

Proso millet has been recovered dating back to the end of the third millennium BC on European archaeological sites and foxtail (Italian) millet has been cultivated since the Bronze Age *circa* 2000 BC in Europe. Proso and foxtail millets were used during the Roman Empire, *circa* 753 BC–610 AD.

The intrinsic attributes of common and Italian millet's hardy and food-insurance nature augur well with traditional Roman values, connecting Romans with their perceived past as a conservative, hardy agrarian people living off the land. Based upon limited ritual evidence, common and Italian millet were likely traditional Roman foods that continued to be offered to the gods. Hence, common and Italian millet appear to fit into the model of the conflicted Roman psyche of traditional agrarian values and the reality of expanding new frontiers and increasing influx of foreign foods and ideas within the empire.

Wall painting of common millet (left) and Italian millet (right) being eaten by two quails (NMinv. No. 8750) from Pompeii, Italy *(Natural History of Pompeii). NB: It is possible to distinguish the two plant species and their similarity to modern species of common millet and Italian millet* Copyright Cambridge University Press/ S. Jashemski

Millet can be boiled and made into a porridge or ground into a flour and made into a heavy flat bread. Greek physician and author Philotimus (4th-3rd century BC) wrote that one way of preparing millet is 'pound it raw, ground finely and, after some water has been poured on, it is pounded once again, strained, boiled' (Oribasius I.15.2).

The presence of millet within the majority of properties with Insula VI.I and other elite houses within the city of Pompeii (80 BC) suggests that millet may have been consumed by the wealthy Roman owners and their servants and slaves.

As the ancient author Strabo (Geography 5.1.12; around 20 BC) advised, 'millet is the greatest preventive of famine, since it withstands every unfavourable weather, and can never fail, even though there be scarcity of every other grain'.

Palaeodietary studies have identified the food changes between Neolithic and Bronze Age human groups in northern France which were probably linked to the introduction millet.

"If you want to waste your time, scatter millet and pick it up again"

(*moram si quaeres, sparge miliu[m] et collige*)

A proverb scratched on a column in the peristyle of the House of *M. Holconius Rufus* (VIII.4.4) around 80 BC at Pompeii (Jashemski *et al.* 2002, 137).

During the nineteenth century, however, the millets were gradually superseded by wheat, rye, rice, maize and potatoes in Europe owing, in part, to the increased popularity and use of raised bread and to some extent by increasing the substitution of cereals by potatoes and other vegetables. However, the production and consumption of millets has persisted to a greater extent in Eastern Europe and Russia, where they are still used in certain parts for cooking, baking, brewing or for other purposes.

Around 100s BC, people in West Asia and Europe were growing both the Chinese millets. But in the southern Mediterranean, people were eating African pearl millet, and pearl mill*et al.*o spread from Eastern Africa south down the coast and became more and more common in southern Africa too. By this time, people in China were making wine out of proso millet, while in Africa, people made beer out of pearl millet and finger millet.

Today millet is a minor food crop and attracts relatively little scientific attention, but it was once among the most expansive cereals in geographical terms. We have been able to follow millet moving in deep history, from where it originated in China and spread across Europe and India," said Professor Martin Jones from the University of Cambridge's Department of Archaeology and Anthropology.

Japan and Korea

Millets and their wild ancestors, such as Japanese origin barnyard grass and Chinese origin proso millet were also cultivated in Japan during the Jomon period some time after 4000 BC. Although a hunter-gatherer economy was the main

subsistence of this region, the millet cultivation was naturally accepted as a part of subsistence strategy, and foxtail and common millets were locally developed as foodstuffs that can be stored. Palaeo ethnobotanists have found evidence of the cultivation of millet in the Korean Peninsula dating to the Middle Jeulmun pottery period (around 3500-2000 BC). Millet continued to be an important element in the intensive, multi cropping agriculture of the Mumun pottery period (about 1500-300 BC) in Korea.

Awaokoshi, candied millet puffs, are a specialty of Osaka, Japan. This millet confection tradition began when it was presented to Sugawara no Michizane when he stopped in Naniwa during the early Heian period, about 1000 years ago

Photo: Mugu-shisai/ Wikimedia commons

Journey to India

Proso millet is an early introduction into India, and it was extensively cultivated in the country. In Sanskrit, it was called Cheenaka , Kakakangu, Kangu and aNu. Crop remains of proso millet have been found in Gujarat during first half of second millennium BC.

A feral rosy-faced lovebird eating millet seeds in Chicago, USA

Source: *David González Romero/Flickr /*

Similarly, foxtail was recovered from the earliest strata of Rojdi (Saurashtra) in pre-Harappan period. In Sanskrit, it has been referred to as BhAvajJ A, Priya GgukA, Rajika, *etc.* confirming its ancient cultivation. It occurred in Harappa levels (2500-2200 BC) at Shikarpur (Kutch) and late Harappan levels (1900-1400 BC) at Punjab. More about domestication and spread of these millets in India will be discussed in the next part.

Millets in USA

In 1849 a distribution of foxtail millet seed was made by the United States Patent Office," and in 1889 millet had become a rather important crop in the Central States, where it was found better adapted than along the Atlantic coast. By 1899 over 74 per cent of the total acreage of millet was found in the North-Central States. Kansas, with 349,906 acres, led all the States, and produced an average of 1.9 tons of millet hay per acre, against an average of 1.6 tons per acre for the whole United States. The total production of millet for the United States in 1899 amounted to 1,743,887 acres and 2,850,959 tons of hay. It is quite probable that 90 per cent or more of this acreage was made up of the foxtail millets.

Sorghum, pearl millet and finger millet were domesticated in Africa

The most prominent and well known millets are the large or great millets of Africa, *Sorghum* and *Pennisetum*. These two taxa account for the majority of millet grain produced around the world. While these small seeded grasses account for less than one per cent of food grain produced in the world today, they are essential food crops in some regions today.

Ethiopia and Eritrea have been a pivotal region for prehistoric contacts between Africa, Asia, Egypt, and Southwest Asia for the past 4000 years.

Evidences indicate an early dispersal (before 2000 BC), of sorghum, finger millet, and tef out of Ethiopia and Eritrea regions of Africa suggesting the existence of earlier local domestication events. Although the African origin of these species has been established by botanical and cytogenetic studies, in several cases the earliest evidence for these crops is outside Africa.

For example, the earliest known archaeological finger millet is found in India dating to the second millennium BC. Tef appears in the form of pottery impressions at Hajar bin Humeid, a site in southern Yemen dating to the first century BC. Although there is a report of sorghum in the Khartoum area dating to the sixth millennium BC, the earliest confirmed archaeological specimens appear in India by at least 2000 BC, probably arriving *via* trade routes from Yemen or other parts of the A*rabi*an peninsula. Claims have been made for the presence of sorghum in North and South Korea during the Plain Pottery Period (*ca.* 2000-500 BC).

Sorghum

Sorghum domestication started in Ethiopia and sub-saharan Africa some 5,000 to 6,000 years ago. The largest diversity of cultivated and wild sorghum is also found in this part of Africa.

Based on the presence of wild sorghums, the possible areas of domestication of sorghum have been predicted to be the eastern Sahara-Nile valley, the lake Chad region and the inland Niger delta.

Another report indicated that the origin and early domestication of sorghum took place in north-eastern Africa, north of the Equator and east of 10°E latitude, approximately in 3000 BC. Archeological evidences in Sudan indicate sorghum cultures around 2100BC. Sorghum adapted to a wide range of environments throughout Africa, spreading from the highlands of Ethiopia to the semi-arid Sahel. Through farmer selection numerous improved sorghum types

were developed, which then spread via trade routes into other regions of Africa and India and eventually worked its way into Australia.

Sorghum was domesticated in Africa where it is still a major food crop

The Indian domestication of sorghum

The secondary center of origin of sorghum is the Indian Subcontinent, with evidence for early cereal cultivation dating back about 4,500 years.

It has been hypothesized that the first truly domestic sorghums came from the Durras of India. According to this theory, the early Bicolors were transported from Africa along the Sind-Punjab trade routes to India around 1000 BC and the Durras later came in from India through the Middle East and down the Nile.

Sorghum in China

There are no confirming reports on exact period of sorghum travel to China. According to some reports, sorghum was one of the important food crops widely grown during the Zhou and Western Han dynasties (11th to 3rd BC), in the present Jiangsu, Shaanxi, Shanxi, Hebei and Liaoning provinces. The presence of durra types

in Korea and adjacent Chinese provinces suggests that it may have been introduced there via the ancient Silk Routes from Asia Minor.

Sorghum (Kaoliang) has occupied an increasingly important place in North China ever since Yuan times (1271 – 1368 AD), and has gradually replaced proso millet in many regions. The grain yields of the two crops are roughly equivalent, but the chief attraction of kaoliang as compared to millet is its greater resistance to flooding and its very high yields of stover, which eventually overcame the Chinese farmer's reluctance to abandon the more appealing traditional food-crop.

***Báijiǔ* : White alcohol, major beverage of China, made from sorghum**

Baijiu, a distinctive white spirit made mainly from sorghum, is known as China's national drink and is considered by some to be beneficial to health and wellbeing. It makes up one-third of the world's total liquor output and is worth an estimated $23 billion annually which is mainly distilled from sorghum fermented in pits or earthenware jars. It is not precisely known when baijiu was invented, however it is generally accepted that it appeared during the Song Dynasty (960–1279AD).

Sorghum arrived in the Near East

Despite the antiquity of sorghum, it arrived late to the Near East. It was unknown in the Mediterranean area into Roman times. During the Arab Agricultural Revolution (8th to 13th Century AD), sorghum was planted extensively in parts of the Middle East, North Africa and Europe. Tenth century records indicate it was widely grown in Iraq, and became the principal food of Kirman in Persia. In addition to the eastern parts of the Muslim world, the crop was also grown in Egypt and later in Islamic Spain. From Islamic Spain, it was introduced to Christian Spain and then France (by the 12th century). In the Muslim world, sorghum was grown usually in areas where the soil was poor or the weather too hot and dry to grow other crops.

Tabling and cutting broom corn Orange Judd company (1908)

Sorghum comes to USA

Sorghum was relatively new to the American continent. It is supposed that grain sorghum was first introduced to North America through the West Indies by African slaves during the seventeenth century. In the U.S., the first known record of sorghum comes from Benjamin Franklin who wrote about its application in producing brooms in 1757. Broomcorn is a type of sorghum that is used for making brooms and whiskbrooms. The broomcorn plant was first described in Italy in the late 1500s.

The introduction of grain sorghum into America occurred in California in 1874, and shortly after that it became widespread in the southern Great Plains and other arid regions of the United States as it was recognized as a drought-tolerant crop that would outperform maize. Over the centuries, sorghum has planted its roots in many states, and crossbreeding has created many of the commonly consumed varieties. It was extensively used in the early 1900s for syrup. Its cultivation in Central and South America has become significant only since 1950.

Sorghum harvesting in USA **Credit:** *USDA / CC BY 2.0*

Pearl millet

Pearl millet grows wild in the Sudan (South of the Sahara Desert) in Africa. Based on the presence of wild relatives, southern edge of Sahara has been considered area of domestication of pearl millet. By 4000 BC, people in the Sudan

Islands of Lake Chad: Buduma women pounding pearl millet

Photo: *Jacques Jangoux/Photoshelter*

were farming pearl millet, and from there pearl millet spread to East Africa and then to Egypt by around 3000 BC. Pearl millet, around 2500 BC spread rapidly to other African countries through pastoralists, spurred by the increasing desiccation of the Sahara desert at the time.

The Egyptians made a flat bread like pita bread out of pearl millet.

From East Africa pearl mill*et al.*o spread to India, where people were farming it by about 2500 BC. The Harappans also used millet to make roti.

It was introduced into India very early, probably by sea-route, as it is not found in Nile valley and Near East for possibility of a land transfer.

In India, well-founded archeological remains of pearl millet (1000-2200 BC) have been obtained from several sites in Harapan culture, Gangetic Plains, and Deccan Peninsula. This suggests its first introduction to North India, followed by its spread to other parts, reaching South India by 1500 BC as revealed by archaeological remains at Hallur of district Haveri in Karnataka.

By 100 BC, pearl mill*et al.*o spread from Eastern Africa south down the coast and became more and more common in southern Africa too. By this time, people in

China were making wine out of proso millet, while in Africa, people made beer out of pearl millet.

In southern India and Africa there is evidence that millet cultivation appears to be an independent process preceding the introduction of other crops. The availability of African varieties of millet during the last 400 hundred years within India has marginalized the smaller, indigenous pearl millets that had been utilized since 5500 BC. Some ancient landraces or ''lost millets'' are no longer cultivated in some areas, but previous research suggests that some were very important in local economies and for the sustenance of many localized communities in southern India from 5500 BC until at least 1600 AD.

Finger millet

The center of domestication of finger millet is controversial. Based on the varietal diversity, India was suggested to be one of its homelands. Whereas, based on occurrence of its probable ancestor, the wild tetraploid *Eleusine africana* in the Ethiopian region, which crosses freely with cultivated finger millet, besides nomenclature and language suggested African origin. Record of carbonized seeds of cultivated finger millet associated with Iron Age in Zimbabwe (Inyanga) corroborate it.

Finger millet field day in Kenya ***Photo:*** *ICRISAT/Flickr.*

From African highlands, finger millet was taken to India and to Europe at the beginning of the Christian era. Later, the crop was widely distributed both in many African countries as well as in the Indian subcontinent.

Discovery of finger millet grains in Harappan period of 2300 BC suggest direct or indirect connections with African populations prior to 2600 BC. Probably, it travelled to India at the same time as sorghum and pearl millet did.

In Sri Lanka, it is known as 'kurakkan' or 'kurahan' and mentioned in legends of ancient kings. It is a tropical crop, grown from sea-level to 3,000 masl. This is the most widely grown small millet in India and Africa, and can be very productive.

Barnyard Millet has its origins in Japan

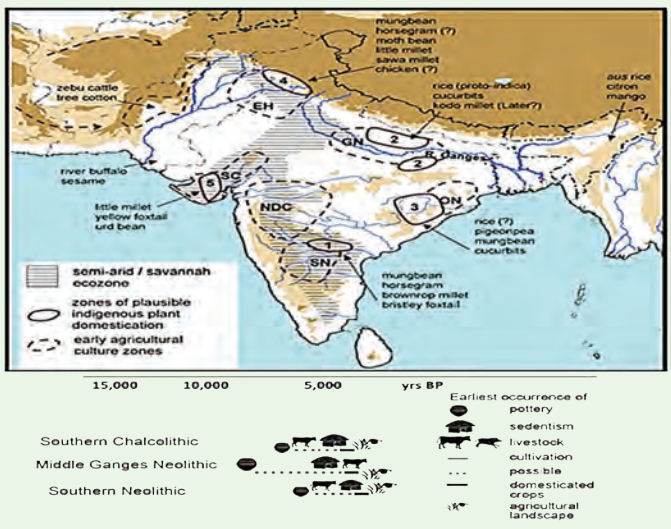
Japanese barnyard millet (*Echinochloa crusgalli*) is native to temperate Eurasia and was domesticated in Japan some 4000 years ago. Barnyard millet (*E. colona*) is widely distributed in the tropics and subtropics of the Old World, and was domesticated in India, where it remains an important cereal in some areas. It has also been recorded from the Central African Republic, Tanzania and Malawi.

Millets of Indian origin

Little millet, kodo millet and brown top millet are the heritage crops of India. Though botanical correlations suggest that they might have originated in other regions, were domesticated in India.

Little millet

Little millet is grown to a limited extent in India, up to altitudes of 2,100 m. It occurs wild in northern India and southeastern Asia. At the Indus Valley Civilisation of Harappa and Farmana, little millet cultivation peaked at around 2600 BC, accounting for around 5% of the total cereal assemblage. It will yield some grain



Zones of early farming Neolithic/ Chalcolithic culture areas depicting brown top millet domestication

(1) Southern Neolithic – where brown top millet was domesticated

(2) Middle Ganges and/or Vindhyas Neolithic

(3) Odisha Neolithic in the Upper Mahanadi,

(4) Eastern Early Harappan in the Foothills of the Indo-Gangetic Divide

Source: Fuller (2011)

and useful fodder under very poor conditions. Some forms mature in as little as two-and-a-half months.

Brown top millet

It was domesticated in South Asia during the 3000 BC, probably with two independent centres of domestication in southern and northwestern India. Brown top millet spread out from the Deccan to Tamil Nadu in the south and Gujarat in the north by the end of the second millennium BC. During this period, local millets and legumes such as green gram and horse gram were incorporated into an agro-pastoral system, part of the ash-mound culture of the southern Neolithic of India, which employed both mobile cattle pastoralism and small-scale crop cultivation. Over time, brown top millet has seen reduced use, although it was still present at the site of Paithan in Maharashtra up to the seventh century AD. Its gradual reduction in use can be attributed to displacement by more productive millets such as sorghum and foxtail millet.

This millet is still cultivated as a minor crop in some areas of southern India for both human and animal consumption. In the United States as much as 100,000 acres are grown annually chiefly in Georgia, Florida and Alabama for hay and pasture, where it was introduced from India in 1915. It is an inexpensive produce as bird seed for game birds.

Kodo millet

Kodo millet is grown as a cereal in India only, although the wild grass is a widespread tropical weed. Kodo millet was domesticated in India 3,000 years ago and is still being domesticated in Deccan Plateau, where it has become a major food crop. However, the kodo millet plant has origins in tropical Africa and it probably travelled to Indian Subcontinent by unknown means. Spikelet specimen found at archaeological site Malhar in Chhattisgarh (1000 BC) has been linked to this species. The crop has been grown for at least 3,000 years, but there is no clear racial differentiation.

Kodo millet is extensively cultivated in tribal areas of Madhya Pradesh and Chhattisgarh
Photo: *Sahaja Samrudha*

Niche millets of Africa

Tef and fonio are among those millets that were domesticated in African continent and are still grown there almost exclusively.

Harvesting tef in Ethiopia
Photo: *A Davey/Flickr*

Tef

Ethiopia is centre of both the origin and diversity of tef. Many believe that tef originated in the northern highlands of Ethiopia, particularly in Tigray, where it is still an important crop. Some believe that Tef was cultivated in Ethiopia even before the semitic invasion of 4000-1000 BC. The earliest known cultivation of tef ws during the pre-Axumite period from 800 to 400 BC in the northern part of the country. Tef is the sole species in the sub-family Chloridoideae cultivated as a cereal crop.

Tef is-the most important cereal crop in Ethiopia, particularly in the poorly drained, heavy soils that predominate in the Central Plateau.

Nevertheless, the crop has not become important outside Ethiopia.

Inspite of the low productivity, tef is widely cultivated by over six million small-scale farmers in Ethiopia where it is annually grown on more than three million hectares of land, accounting for over 30% of the total cereal acreage.

Fonio

Fonio is considered to be the oldest West African cereal and its cultivation is thought to date back to 5000 B.C. Fonio is a tiny ancient grain that has been grown and celebrated across West Africa for thousands of years and has been found entombed in Egyptian pyramids.

Fonio, also known as hungry rice, is grown as a cereal crop throughout the savanna zone of West Africa. In parts of Guinea and Nigeria it is the staple crop. The crop can grow on poor, shallow and rocky soils, but is not grown outside Africa. *Digitaria exilis* is known as Acha (white fonio) while *D. iburua* is a black seeded form.

Fonio harvesting ***Photo:*** *Toujours Passages*

History of Millets in India

Introduction of millets

The proso millet and foxtail millet, which were domesticated in China, travelled to India probably through trade routes. Archeological data of proso millet and other crops suggested that the Indian valley of Kashmir was integrated into a wider network of crop exchange in the mountainous regions of South and Central Asia during the 3000-2000 BC period.

Millets from China

Foxtail millet spread from China to south and westward to reach India. In Sanskrit, it has been referred to as BhAvajJA, PriyaGgukA, Rajika , *etc.* confirming its ancient cultivation. It occurred in Harappa levels (2500-2200 BC) at Shikarpur (Kutch) and late Harappan levels (1900-1400 BC) at Punjab. Also, it was recovered from the earliest strata of Rojdi (Saurashtra), placed within 400 years of the oldest find of domestication. Carbonized seeds were reported from Jorwe culture levels (Ahmadnagar, 1500 BC) and Daimabad in Mahararashtra.

The mention of millets in Indian Sanskrit text Yajurveda's verses- of foxtail millet (p*riyangava*), proso millet (*aanava*) and Barnyard millet (*shyaamaka*), indicated that millets culture and consumption was very common, dating to the Indian Bronze Age (1,500BC).

Archaeobotanical remains have also been found from upper and middle Gangetic Plains. It was also grown at Manjhi (Saran, Bihar) during the red ware levels (250 BC-250 AD). In South India, foxtail and proso millets were the staple diet for the people from the Sangam period (300 BC to 300 AD). Sushruta (Sushruta Samhita, 600-500 BC) classified cereals as *dhanya varga, khudhanya varga* and *samidhanya varga. Khudhayna varga* includes, among others millets *viz*., kodo millet (kodrusaha), barnyard millet (syamaka), and coix (gavedhuka).

Kalidasa (4-5th AD), in his legendary literary masterpiece '*Abhijnana Shakuntalam'*, has sage Kanva pouring foxtail millet while bidding farewell to Shakuntala in Dushyanta's court, which indicates the auspicious nature attributed to this millet. In the 10th-12th Century AD Varaha purana, it is mentioned that God Srinivasa is favourable to the one who offers foxtail millet. According to *Dakar Bachan*, composed sometime in early medieval Bengal (8th to 13th Century AD),

cultivation of proso millet (china kaon) was advised if it rained during *Phalgun* month (February-March).

African millets transformed late Harappan agriculture in Western and Peninsular India

The Saurashtra Center was dominated by little millet, native small *Setaria* spp. and brown top millet during the Mature Harappan period, 2500–2000 BC.

Arrival of high-yielding African millets led to increase in settlements in the Gujarat region and expansion of cultivation. It is believed that there was a distinct climate change in Gujarat region around 2000 BC and the region became more arid. At this time millets became more predominant in the Harappan subsistence system.

Pearl millet and sorghum from Africa also appear during this time, besides finger millet. Pearl millet was known in the later 3rd millennium BC in Saurashtra and moved to South India where it was known around 1800 BC. Pearl millet was a noticed in Neolithic South India (2000-1200 BC) and Narhan culture (1300-800 BC). However, the millet finds it's mentioning in Ayurvedic texts only since the 14th Cen. AD. It is known to be Nali in Sanskrit and the very first mentioning of the word Nali is found in Madanapala Nighantu (1374 AD) under Truna Dhanya category. The presence of finger millet in India dated to approximately 2300 BC at Hallur, Karnataka, during Harappan levels. This suggests direct or indirect connections with African populations prior to 2600 BC Finger millet has also been reported from late Harappan levels in Northern and Western India. Finger millet was the staple of Neolithic Karnataka.

African cultivars moved to southern India and southern Indian cultivars to Africa as early as the second millennium BC, testament to active networks of exchange and innovation**.** It is believed that arrival of African millets to India coincided with an increase in sedentism and agriculture in Peninsular India. The Hallur site in Haveri district of Karnataka yielded crop cultivation pattern during 2000-1000 BC, comprising of Neolithic-Chalcolithic and early Iron Age. Brown top millet, bristly foxtail (*Setaria verticillata*) and pearl millet (African origin) seeds pertained to Neolithic age (2000-1200 BC), while finger millet (African origin) and kodo millet were Early Iron age dated (1200 to 1000BC).

In the excavations of Oriyo Timbo in the Shavnager district of Gujarat state, 77% of seeds were found to be millets comprising proso millet, little millet, foxtail millet and finger millet. The site has been dated to the first half of second millennium B.C. and the excavators believe that it was a seasonal encampment occupied every year during the months of March to July. The evidence is suggestive of a primary

pre-Harappan agricultural tradition based on native monsoon-adapted crops. As with South India, however, there is no archaeobotanical evidence for the earlier stages of this tradition or for the transition from collecting to farming these species. Evidences indicate cultivation of sorghum during pre-Harappan period (2300-2000 BC) in Punjab.

Late- Harappan phase (1800-1700 BC) of Indus valley civilization was marked by diversification of agriculture, perhaps as a response to climate change to cooler and drier seasons. At Pirak in Baluchistan, double cropping system was in place with pearl millet and sorghum being grown in summer. Excavations at Hulas (Saharanpur) yielded evidence for sorghum and finger millet grains.

Outside of the Indus Valley area of influence there were two regions with distinct agricultures dating back to around 2800-1500 BC. These are the Deccan Plateau and an area within the modern states of Odisha and Bihar.

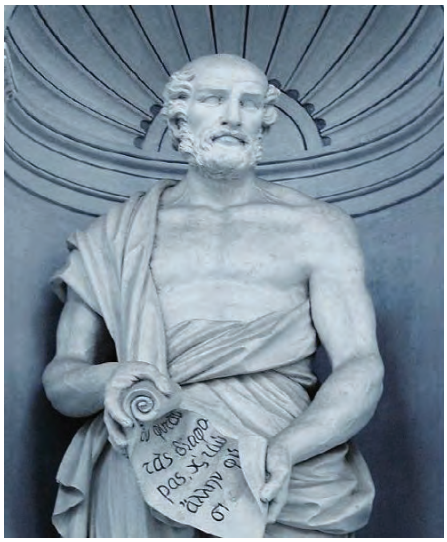
Within the Deccan, the ashmound tradition developed around 2800 BC. The people of the ashmound tradition grew millets and pulses, some of which were domesticated in this part of India, for example, brown top millet, *Setaria verticillata*, green gram and horse gram. They also herded cattle, sheep and goat and were largely engaged in pastoralism. This era may be seen as establishing the basic South Indian repertoire of rainfed millets and pulses, sown in synchrony with the southwest monsoon.

In the east of India Neolithic people grew rice and pulses, as well as keeping cattle, sheep and goat. By 1500 BC a distinct agriculture focused on summer crops, including Vigna and little millet was developed.

Among the chalcolithic culture of the Deccan, the Jorwe farmers (1400-1000 BC) in Malwa practiced *kharif* and *rabi* crop rotation, where sorghum and finger millet were grown along with wheat, barley and rice.

Greek historian Megasthenes (350-290 BC) Mentioned that millets are grown after summer solastice, foxtail millet and sorghum are grown, among others.

During Satavahanas (1st to 3rd century AD) and Vataka dynasty (250-270 AD), sorghum



Greeks historian Megasthenes *was the first foreign envoy and ambassador of Seleucus Nikator, a general of Alexander the Great, to the court of Chandragupta Maurya (302-298 BC) who mentioned about cultivation and consumption of millets in India*

was abundantly used over rice in the Deccan region, which changed gradually The term 'yavanaala' mentioned in Indian text *Charaka Samhita* (100-200 AD) is attributed to sorghum. Greek author Pliny wrote about introduction of sorghum from India to Italy during 60-70 AD. In Vishnu purana (450 AD), gramausadhi group of plants includes cereals, including priyangu(foxtail millet), hyudar'sa (sorghum), korusa (kodo), yajgnausadhis includes priyangu (foxtail millet), syamaka (barnyard), gavedhu (coix), *etc.*

Millets in the Vijayanagara Empire

The Kannada language composition 'Ragi thandheera' written by Purandara Dasa, a 15th century Indian poet, is much celebrated in Karnataka to highlight the popularity of finger millet (ragi) during those times. The Telugu poet Srinatha, who lived in the first half of the 15th century described of the people food habit of Palnadu area in Andhra, a part of the then Vijayanagara Empire, as entire subsistence on sorghum and pearl millet for porridge, fermented products, cooking, *etc.* and that except millets they have nothing to eat. Fernao Nuniz, a Portugese traveller, who visited Vijayanagar Kingdom in 16th century AD, mentioned that sorghum was the major food grain consumed in South India.

Kannada poet Kanakadasa (16th Century) has immortalised finger millet in his 'Ramadhanya Charithre'; it is an allegory on the conflict between the socially strong and weak castes and classes, presented as an argument between two food grains, rice and finger millet (ragi), a most creative literary piece with a powerful social message. Sarvajna, a 17th century Kannada poet who belonged to this period, speaks in glowing terms of sorghum which was and is the staple food of the common people in North Karnataka districts.

Kannada poet Kanakadasa (16th Century) has implied the goodness of finger millet in 'Ramadhanya Charithre'

Indian Millets

Kodo millet

Chalcolithic 1800-1200BC era findings reported kodo millet from Northern and eastern India. The first report of kodo millet from South India is during megalithic age (1000-300 BC) from various places in Maharashtra and Andhra Pradesh. The record from Ganga valley pertained to cultivation during Narhan culture (1300-800 BC). In the *Arthashastra* of Mauryan age (200-300 AD), kodo millet has been referred to as kodrava, grown along with other crops. Ibn Batuta from Morocco who visited

Indian during the times of Muhammad-bin-Tughlak (1325-1351 AD) recorded that kodo millet was the commonest grain.

Kautilya's *Arthashastra says…..*

Kodrava (kodo millet), … and priyangu (foxtail millet) will increase three times the original quantity when cooked; … Grains will increase twice the original quantity when moistened; and two and half times when soaked to sprouting condition.

Little millet

The Saurashtra Center was dominated by little millet, native small *Setaria* spp. and brown top millet during the Mature Harappan period, 2500–2000 BC. In the excavations of Oriyo Timbo in the Shavnager district of Gujarat state dating to 2000-1500 BC, 77% of seeds were found to be of millets comprising little millet, among others. This site was believed to be a seasonal encampment occupied every year during the months of March to July. The evidence is suggestive of a primary pre-Harappan agricultural tradition based on native monsoon-adapted crops.

Kautilya's Arthashastra describes culinary properties of kodo and foxtail millets

Photo: *Timesee CreativeCommons.org*

Brown top millet

This was a major millet in the Mature Harappan period. The Hallur site in Karnataka yielded the evidence for its cultivation in neolithic period of 2000-1500 BC.

S. Moula stands in his intercropped field of tur dal and brown top millet in Madigubba, Anantapur District, Andhra Pradesh. ***Photo:*** *Peter Bakos/AID (2016)*

Millets and Mughals

During Mughals period, in 16-17th Century AD, Pearl millet was grown in dried areas of the northwest and western zones. Further, millets were also cultivated in wheat dominant areas and other drier districts. Sorghum and pearl millet were the two main millets. The *Ain-i-Akbari* (16th century AD) written by Abul Fazl, records that millets which included sorghum, pearl millet, kod millet, barnyard millet and finger millet formed the *kharif* crops and were cultivated in Malwa, Gujarat, Ajmer, Khandesh, Lahore, Agra, Allahabad, Awadh and Multan.

Abul Fazl has given statistics on yields of crops on *Bigha* basis in different cultivation conditions, including that of sorghum and pearl millet.

Francisco Pelsaert of Dutch East Indian Company at Agra (1621-1627 AD) writes that sorghum, pearl millet and foxtail millet were the food grains eaten by the poor in the 17th century.

Abul Fazl, Grand vizier of the Mughal emperor Akbar, and author of Ain-i-Akbari

Mughal ruler Jahangir 1605-1627 AD) relished millet kichdi

Mughal emperor Jahangir (1569-1627 AD), in his autobiography Tuzk-e-Jahangiri, talks about laziza (tasty), a kind of khichdi he encountered in Gujarat. Laziza was a mixture of bajra (pearl millet) and peas cooked together. He writes: 'It was not devoid of good flavour and it suited me well. I ordered that on the days of abstinence, when I partake of dishes not made with flesh, they should frequently bring me this khichdi.'

Mahabat Khan, the Mughal noble who served under Jahangir and Shah Jahan, used to eat only once in 24 hours, and during this meal, his table was laden with two trays each of pulao, ash-ha (broths), and trays of rice and millet khichdi.

Kingdom of Hyder Ali

Hyder Ali Khan (1720 – 1782 AD), the Sultan of the Kingdom of Mysore was, at times, known to consume dry roti of finger millet or sorghum with just water. However, the finger millet, the staple food of his subjects, was always a part of his menu.

James Scurry (1766–1822 AD), a British soldier who was held captive by Hyder Ali and Tipu Sultan for 10 years (1780–1790) at Srirangapatam, wrote that during his march from Bengaluru prison to another place, he was fed with food made from finger millet flour.

Hyder Ali Khan (18th century), Sultan of Mysore, used to consume millets in his diet

Leslie Coleman developed the first finger millet variety in 1918 in Bengaluru

The colonial India

During the colonial period when European nations controlled India, there was no emphasis on millets as the colonizers manipulated agricultural production to suit their needs of imports which included spices, cotton, indigo and other commercial crops. Evidences indicate that from 17th century to 20th century, the productivity of food grains including millets did not rise. Scottish physician Francis Buchanan, who toured across South India in 1807, writes "The crop of *Ragy* [finger millet] is by far the most important of any raised on dry field, and supplies all the lower ranks of society with their common food. Among them, it is reckoned the most wholesome and invigorating food for labouring people; and in every country, most fortunately, a similar prejudice appears to prevail, the most common grain always reckoned the nourishment most fit for the labourer... My *Bengal* and *Madras* servants, who have

been accustomed to live upon rice, look upon the *Ragy* as execrable food, and, in fact, would experience great inconvenience were they compelled to live upon it."

It is recorded that when the Tungabhadra dam was built in the 1940s near Hosapete, Karnataka, "surveyors recall that rice was difficult to obtain; they found eating millets distasteful, an enduring memory of a hardship posting".

It was the interest of Leslie Coleman, a Canadian scientist, who worked for British as the second director of agriculture in Mysore State, when posted in Bengaluru, to initiate research on finger millet. He was farmer-friendly and also ate finger millet 'mudde' with them. He contributed the first finger millet variety too.

Before proper irrigation systems were invented, millet proved to be a very important staple food in African and Asian cultures, due to its drought resistant growth adaptations. Its importance continued until wheat and rice cultivation was perfected. Today, millet continues to be a staple for more than a quarter of the world's population. The arid and semi-arid regions of countries in Africa and Asia produce most of the millets. Consumption of sorghum and millets is typically high in the regions where they are produced, similar to rice. For example, During 2010, even though annual average per capita sorghum and millet consumption was about 8 kg in India, in the states where these crops are grown, per capita consumption exceeded 90 kg. By contrast, even though USA is the leading producer, hardly any sorghum makes it into human foods in the USA, with most of the grain used for animal feed and export. Similar is the case with Argentina and Mexico. However, growing evidence on potential health benefits of sorghum and millets have seen increased interest in their food application.

Worldwide, the millets are grown in 76 million hectares production contributes to 95 million tons of food grains to the 300 million cereal grains basket. Sorghum and pearl millet occupy major area and produce more than 90% of all millets. Yields of millets grown in Africa and India are lower, with the exception of finger millet.

Area harvested, production and yield of millets in the world during 2016

S No.	Millet crop	Area (000 ha)	Production (000 tons)	Yield (kg/ha)	Per cent contribution to total millets production	No. of major production countries
1	Barnyard millet	146.3	151.2	1034	0.2	2
2	Finger millet	2106.3	3417.7	1623	3.6	9
3	Foxtail millet	1057	2290.0	2166	2.4	3
4	Kodo millet	200	84.2	419	0.1	1
5	Little millet	255.5	119.9	469	0.1	1
6	Pearl millet	27161	23092	850	24.3	40
7	Proso millet	944.1	1449.5	1535	1.5	36
8	Sorghum	44771	63931	1428	67.3	91
9	Fonio	741.6	645.2	870	0.7	9
	Total millets	**77237**	**95030**	**1230**		**131**

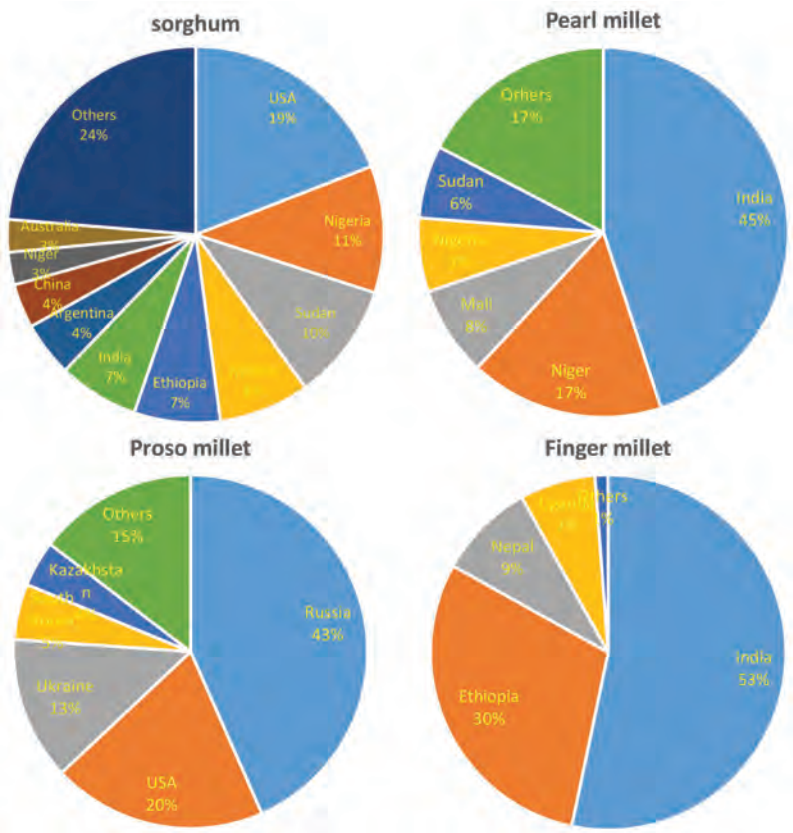
Source: *IIMR estimates based on FAO/DES-GOI data*

Production of millets in major millets producing countries during 2016

	Barnyard millet				
1	India	146.0	151.0	1034	99.9
2	Japan	0.3	0.2	837	0.1
	Total	**146.3**	**151.2**	**1034**	
	Foxtail millet				
1	China	746	1995.9	2675	87.2
2	Myanmar	238	243.4	1023	10.6
3	India	72.6	50.2	691	2.2
	Total	**1057**	**2290.0**	**2166**	
Kodo millet					
1	India	200	84.2	419	100
	Total	**200**	**84.2**	**419**	
	Little millet				
1	India	255.5	119.9	469	100
	Total	**255.5**	**119.9**	**469**	

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

Contribution of different countries to world millets production (2016)



Millets in Asia

India is the leading producer of most of the millets, including major ones – sorghum, pearl millet and finger millet and ranks first or figures in top ten producer countries. However, the yield levels of millets in India are low, as most of the cultivation happens in resource poor soils in rainfed conditions with least or no inputs. China produces more than 2 million tons each of sorghum and pearl millet with yield levels of about 4500 kg and 2600 kg per hectare respectively.

Contribution of India to Global Millets Production during 2016

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*

Except for sorghum and pearl millet, others are grown in far lesser area and in fewer countries as well. While finger millet is grown in mainly in South Asia India and East Africa, foxtail millet in confined to China, Myanmar and India. Proso millet is grown in 36 countries, but only in limited area. Barnyard, millet, little millet and kodo millet are mostly confined to the India with no significant cultivation elsewhere.

The millet grinding competition in Taiwan uses a traditional mortar and pestle, and requires synchronized teamwork

Source: *Tony Coolidge*

Foxtail millet is by far the single most important millet in China. The growing area has declined since the 1980's due to an increase in maize. Still, China produced more than 90% of the world's foxtail millet output in the 1980s. China produces nearly 2 million tons of foxtail millet a year.

Proso millet, which is also known as common millet, can be found in regions of Asia, led by Russian Federation. It is widely used in Slavic countries and America, mostly for fodder and compost.

In USA, taking advantage of its low resource demand and lack of disease, farmers use it as a catch crop. Proso millet helps avoid summer fallow and allows for continuous crop rotation. The millet is able to grow from the run off and doesn't damage the soil, allowing it to replenish its nutrients in time for the next crop cycle.

Finger millet is the fourth major cereal crop in Nepal, cultivated in 274,350 hectare with an annual production of 302 thousand metric tons, being highly suited to marginal and low external input agriculture. Finger millet grains are used to brew local alcoholic beverages, owing its significance in the local culture of some ethnic communities. It has the potential to improve food security, health, income, livestock production and overall development of smallholders living in marginal lands.

Barnyard millet is mainly cultivated in areas where climatic and edaphic conditions are unsuitable for rice cultivation. In India, barnyard millet is grown from Himalayan region in the north to Deccan plateau in the south. It is generally cultivated in hill slopes and undulating fields of hilly, tribal or backward areas, where few options exist for crop diversification. In the past, Japanese barnyard millet was important in Japan as the staple food crop in districts where soil, weather conditions and irrigation systems were not suitable for paddy rice cultivation. When the rice crop suffered serious cool weather damage, the millet relieved people from starvation, especially in northeastern Japan. But the acreage devoted to the millet gradually decreased during and after the 1880s. Only the northern part of Iwate Prefecture is a Japanese barnyard millet cropping region at present. The breeding of cool-weather-resistant rice varieties and improvements in rice- growing techniques are mainly responsible for the decrease in acreage of the millet.

Millets in Africa

Millets are extremely important in the African semi-arid tropics, produced by 28 countries covering 30% of the continent. There are nine species which form major sources of energy and protein for about 130 million people in Sub-Saharan Africa. Among these, only four are produced significantly in Africa; including sorghum, pearl millet, finger millet, tef and fonio. Millet production is distributed differentially among a large number of African countries; largest producers being in West Africa led by Nigeria, Niger, Burkina Faso, Mali, Senegal and Sudan. Finger millet is produced mainly in East and Southern Africa.

Pearl millet harvest produce in Africa

Across Africa several indigenous foods and drinks are made from flour/meal and malt of the millets. Millets are consumed as staple food (about 78%), drinks and other uses (20%). Feed use is still very small (2%). During 2010, in Burkina Faso and Sudan, per capita consumption of sorghum and millets was more than 80 kg, whereas the figure exceeded 90 kg in Niger (where millet accounts for 80% of cereal grain consumption). In Nigeria, which is a major producer of sorghum, per capita sorghum consumption is about 50 kg.

The Sahel region in Africa that includes Burkina Faso, Chad and Gambia has millet taking up about 33 percent of the population's daily cereal food consumption. Mali and Senegal rely on the cereal crop to take up 40 percent of their daily calorie count. Countries that face severe famine such as Ethiopia, Nigeria, and Uganda have a heavy reliance on millet, making it their major source for carbohydrates each day.

Millets in USA

Millets are grown extensively in Africa, India, China, Korea, Japan, and Russia the for human food whereas in the United States of America, all except the broom-corn millet are used almost exclusively for forage purposes.

USA is the leading producer of sorghum more than 70% of which is exported to China and other countries. Some area is under pearl millet for fodder purposes. Production of other millets in the Americas has largely been restricted to limited special uses as an emergency grain crop, for fodder and birdfeed.

The small size of millets seeds relative to the mature plant size (compared with other cereals and maize) with corresponding low seed requirements and the ability of several species to produce more grain than other cereals under conditions of intense heat, scanty rainfall, short seasons, and medium soil fertility levels are important advantages for both multiple cropping and the growing of emergency or catch crops. Proso millet is the only millet grown as a grain crop in the United States. Other millets as foxtail, Japanese or barnyard, and pearl millet or cattail are grown mainly for forage or pasture.

ICRISAT-HOPE and McKnight seed projects hold pearl millet field day in Niger

Photo: *Flickr/ICRISAT*

Proso, or broom-corn millet, is more distinctively a grain millet, and it has been used to some extent in North Dakota and South Dakota as a grain crop. Proso millet is probably grown on not more than 50,000 acres in the United States, though actual data are unavailable. Most production is in the Northern Plains and other short-growing season areas. In America, taking advantage of its low demand and lack of disease, farmers' use it as an intercrop. Proso millet helps avoid summer fallow and allows for continuous crop rotation.

Foxtail millet is grown chiefly as a catch crop. Most farmers use it to overcome an expected shortage in their hay supply or to occupy a field which would otherwise be idle on account of the failure of a regular crop or because climatic conditions have prevented the seeding of such a crop. Millet is admirably suited to such use because of its short season of growth and the ease and certainty of obtaining a stand. Large yields are not obtained either on poor soils or in dry climates, but millet has been found to make a heavier yield under such conditions than most other hay crops.

The strongest competitor of millet which has yet been found is Sudan grass, a type of sorghum, which promises to replace millet in many localities as a catch crop. The quality of Sudan grass hay is superior to that of millet, and its yields under comparable conditions are nearly always larger, but the growing season is a trifle longer than that required by either proso of foxtail millet.

Brown top millet is grown in southeastern United States for hay or pasture and bird and quail feed plantings on game preserves.

Millets in India

India is the leading producer and consumer of millet crops and their products. The people in arid and semi-arid regions of the country grow and consume millets as staple food. Grain and fodder yielding 'dual purpose' millets are grown basically to ensure food and fodder security in the rainfed agriculture.

Production Scenario

A total of about 12.5 m tonnes of millets food grains are produced in India from nearly 14.6 m ha area, which constitutes 7% of national food grain basket. Pearl millet is grown in about 7.1 million hectares yielding 10.3 million tons, followed by sorghum (5.7 m ha, yielding 4.4 m ton) and finger millet (1.1 m ha, yielding 1.82 m ton) and other millets (0.7 m ha yielding 0.4 m ton). These crops are grown for both grain and fodder purpose.

Much of the grains are consumed at house hold levels and the rest goes for industrial uses including for poultry feed, food processing and breweries. Some quantities are also get exported as seed, bird feed and processed food items.

Estimates (Mean of 2010-11 to 2014-15) of Area, Production and Yield of Millet Crops in India

Crop	Season	Area (million ha)	Production (million ton)	Yield (kg/ha)
Sorghum	*Kharif*	2.53	2.85	1126
	Rabi	3.83	3	783
	Total	**6.36**	**5.85**	**913**
Pearl millet	*Kharif*	8.16	9.56	1172
Finger millet	*Kharif*	1.2	1.95	1621
Small millets	*Kharif*	0.72	0.43	596
Total Millets	**Total**	**16.45**	**17.79**	**1076**

Source: *Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Government of India.*

Though millets are one of the earliest grains that are being cultivated and consumed by the people, in the last few decades India and the world have witnessed significant decrease in the area under the millets crops. However, the productivity of these crops has gradually gone up due to adoption of high yielding varieties and improved production technologies. Among the states, maximum area under millets is in Rajasthan (5 m ha; 87% under pearl millet) followed by Maharashtra (4 m ha, 75% under sorghum) and Karnataka (2 m ha, 54% under sorghum, 32% under finger millet).

Area (million ha), production (million ton) and productivity (kg/ha) of millets in India

Sorghum	Area	17.36	17.68	16.09	16.10	11.33	8.68	6.18
	Production	6.73	7.58	9.50	10.20	9.33	7.63	5.33
	Productivity	387	429	591	633	823	880	863
Pearl Millet	Area	11.34	11.97	11.57	10.65	9.32	9.58	7.20
	Production	3.43	3.75	5.74	3.66	5.38	7.68	8.74
	Productivity	302	314	496	344	577	802	1214
Finger Millet	Area	2.30	2.70	2.63	2.41	1.77	1.53	1.11
	Production	1.85	1.33	2.80	2.52	2.50	2.35	1.59
	Productivity	800	492	1064	1049	1410	1534	1428
Small Millets	Area	5.34	4.56	4.67	3.16	1.66	1.06	0.75
	Production	2.07	1.56	1.92	1.22	0.78	0.47	0.43
	Productivity	388	341	412	386	469	443	571

Source: *Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Government of India.*

The area, production and consumption of millets in India have come down in the recent decades both due to demand side and supply side factors. There lies significant gap in both the demand and the supply side. On the demand side, the consumption of millets have come down due to increased consumption of other fine cereals, negative perceptions of millets as a food for the poor and policy neglect when compared to other crops. On the supply side, limited productivity of crops and their growing situations and lack of their processing centres in the vicinity which prevents the farmers from realizing additional yield benefits from the improved package of practices and additional income generation.

The main reasons for declining the millets crops in India were found to be low remunerative as compared to other competing crops, lack of input subsidies and price incentives, subsidized supply of fine cereals through PDS, and change in the consumer preferences. These have led to shift from production of millets to other competing crops such as soybean, maize, cotton, sugarcane and sunflower in the country as a whole.

Sorghum harvest in South India *Photo: Flickr/ICRISAT*

Sorghum

In India, this crop was one of the major cereal staple during 1950's and occupied an area of more than 18 million hectares but has come down to 6 million hectares in 2013. The decline has serious concern on the cropping systems and the food security of these dry land regions of the country. However, the enhanced productivity sustained the production levels of the crops though per capita sorghum production came down drastically. The yield increased from 387 kg/ha during 1955-56 to 863 kg/ha in 2012-13 due to adoption of new cultivars and production technologies. However, this is much below the world average. One reason being that the *rabi* season sorghum is a moisture-stressed period of cultivation and productivity is quite low which has much substantial area.

Pearl Millet

In terms of annual production, pearl millet is the sixth most important cereal crop in the world. In India, five states (Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana) account for nearly 95% of the pearl millet cultivated area. Pearl millet is often grown on infertile soils and under water-limited conditions where no other cereal crop can be successfully grown. Its is valued for both grain and stover as its grain is the major source of dietary carbohydrates of human diet in western India and stover forms the basis of livestock ration during the dry period of

year in north Indian states. This millet is rich in energy and minerals. Bio-fortified varieties are also available. The research efforts targeted to enhance productivity through breeding high yielding cultivars and refinement in production and protection technologies have resulted into increase in pearl millet productivity from 314 kg/ha in 1950 to 1255 kg/ha in 2014-15. The total pearl millet production has also been increased from 2.6 m tons to 9.2 m tons.

Small Millets

The 'small millets' category in India encompasses of finger millet (ragi), foxtail millet (kangni), kodo millet (kodo), proso millet (cheena), barnyard millet (sawan) and little millet (kutki). Considering the extent of acreage under each of these crops, they have been ignored by policy makers and R&D stakeholders. However, they are of local importance as staples and as reserve crops in marginal areas. They are grown from sea level to mid hills right from Tamil Nadu in the South to Uttarakhand in the North, and Gujarat in the West to Arunachal Pradesh in the Northeast.

Small millets are grown in a variety of agro-ecological situations *viz*., plains, coast and hills as well as in diverse soils and varying rainfall, widely differing in thermo and photoperiods. They are known for resilience and drought enduring capacity and are relatively less prone to major pests and diseases. These are indispensable in tribal and hill agriculture where crop substitution is difficult.

Small millets in India are grown in Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Odisha, Jharkhand, Chhattisgarh, Madhya Pradesh and Uttarakhand. They being the components of traditional farming system one could see well evolved cropping systems.

The area under these small millets during the last 6 decades has significantly shrunk from 8 million in 1949-50 to around 1.8 million in 2014-15. This is also reflected in diminishing production, from around 4 million tons produced in late forties to around 2.44 million tons in 2014-15. The loss of area is very severe in all small millets other than finger millet. This was due to doubling of productivity of finger millet from 704 kg/ha to 1706 kg/ha and wide spread cultivation of high yielding blast tolerant varieties. However, in the last 15 years, the finger mill*et al*.o has lost ground and area has come down from 2.4 million to 1.2 million ha and likely to lose further in the coming years.

By and large, the low productivity of these crops is largely due to meagre attention received in terms of inputs; water and technology backup which is further compounded by low value status of grains.

Finger millet area, production and productivity in Finger millet in recent years (Average of 2009-10 to 2014-15)

State	Area (lakhs ha)	Production (lakhs tons)	Productivity (kg/ha)
Karnataka	7.02	13.25	1887
Maharashtra	1.25	1.34	1070
Uttarakhand	1.22	1.68	1372
Tamil Nadu	0.87	2.24	2580
Other states	1.66	1.40	843
All India	**12.02**	**19.91**	**1656**

The major finger millet growing states are Karnataka, Uttarakhand, Maharashtra, Tamil Nadu, Odisha, Andhra Pradesh and Gujarat. Of the total area under finger millet Karnataka alone occupies 58.4% followed by Uttarakhand and Maharashtra with 10% each.

Karnataka contributes nearly 66.5% of finger millet production in the country followed by Tamil Nadu and Uttarakhand with 11.2% and 8.4%, respectively. Tamil Nadu has the highest productivity (2580 kg/ha), followed by Karnataka (1887 kg/ha) and Uttarakhand (1372 kg/ha).

Other Small Millets

In other small millets, the area declined is very drastic leading to lowering of production without any visible increase in productivity. This is largely attributable to confinement of these crops to marginal areas, non-availability of quality seed of improved varieties and poor extension support.

Area, production and productivity in other Small Millets in recent years (Average of 2009-10 to 2014-15)

State	Area (lakhs ha)	Production (lakhs tons)	Productivity (kg/ha)
Madhya Pradesh	2.24	0.79	352
Chattisgarh	1.12	0.29	258
Uttarakhand	0.71	0.88	1239
Maharashtra	0.59	0.30	508
Gujarat	0.43	0.46	1069
Other states	1.65	1.41	854
All India	**6.74**	**4.13**	**613**

Madhya Pradesh (33.2%) has the largest area under other small millets, followed by Chhattisgarh (16.6%) and Uttarakhand (10.5%). Uttarakhand and Madhya Pradesh contribute 21.3% and 19.1% of small millets production which is closely followed by Gujarat 11.1%. Productivity of other small millets as a whole is high in Uttarakhand and Gujarat.

Consumption pattern

Sorghum and other millets are the staple food of western and central regions of Maharashtra and the northern region of Karnataka and Andhra Pradesh. The annual per capita consumption of sorghum is declined by 75% in urban areas, and 87% in rural areas during 1972-73 to 2011-12.

In the last two to three decades sorghum grain, especially sourced from *kharif* season are diverted to industrial uses such as livestock and poultry feed, starch, potable alcohol and ethanol production due to poor quality and mould affected grains.

The declining trend in sorghum consumption and other nutritious cereals in general is attributed to the shift in dietary patterns of consumption towards a balanced diet that includes livestock products, fruits and vegetables (Chand, 2007) which is mainly driven by an increase in income and urbanization wherein people are too busy to spend much time in preparation of their daily diet. Secondly, the shift is due to the consumption of fine cereals which are supplied through PDS at subsidized prices.

Trends in Direct Consumption of Sorghum vs major Cereals in India

Kg/person/year

Commodity	1973-74	1983 -84	1993-94	2004-05	2011-12
Rural					
Rice	84.0	80.7	85.4	78	71.7
Wheat	42.8	54.3	53.5	51	51.5
Sorghum	**19.0**	**12.5**	**9.7**	**5.16**	**2.4**
Urban					
Rice	65.5	64.7	64.2	57	53.8
Wheat	52.6	58.6	57.4	53	48.1
Sorghum	**11.0**	**6.0**	**4.9**	**2.7**	**1.56**

Exports of millets

A modest quantity of 160,000 to 240,000 tons of millets were exported annually during past three years, much of it being seeds and grains of sorghum and pearl millet.

Millets are Least-demanding and Most Sustainable Crops

Millets represent a diverse group of versatile cereals that have long been a part of many agricultural ecologies in Eurasia and Africa, but especially in more arid and tropical regions. Millets are generally well adapted to low-rainfall regimes, short growing seasons, and poor soils. They are therefore often the most reliable cereals in many marginal environments. Most millets are reported to be drought tolerant, although a few such as finger millet are usually grown in somewhat wetter conditions and on good soils in order to produce high yields. These food crops are unique as they require less water to grow, mature early and are cultivated in low input conditions. At the more extreme end of drought tolerance are proso millet in Eurasia and pearl millet in the hot and dry parts of Africa and India, both of which may grow with 300 mm of rainfall or less and mature rapidly (within three months).

Since centuries, the millets have provided food and nutritional security to the populations in the disadvantaged geographical regions. Agronomic advantages e.g. highly adapted to low rainfall conditions, able to withstand fairly long dry spells, recover fast after delayed rain, make them good contingent crops.

Millets are highly resilient in adapting to different ecological conditions; ideal crops for climate change and contingency plantings. Being C4 plants these are more environment friendly with high water use efficiency and low input requirement, but equally responsive to high input management.

In addition to these agronomic advantages, millets can offer other benefits in ecological, nutritional, and socioeconomic areas. Besides being farmer-friendly, the unique nutritional properties of millets, *i.e.,* high fiber, quality protein & mineral composition, being called as "Nutri-cereals".

Millets are looked upon as offering greater comparative advantages compared to other food crops owing to their rich nutritional profiles, income augmenting opportunities, and resilience to climate change. Utilization of millets as food crops represents an interesting opportunity to contribute filling the gap in food supply. For instance, as estimated by West *et al.* (2014), increasing yields by 50% of the potential yield in all low-performing areas could increase annual production by 8.46×10^{14} kcal, which is enough to meet the basic caloric requirements of ~850 million people. The yield gap in millets is largely a reflection of farmers' cultivation technologies that offer ample room for improvement. Seed is usually farm-saved and of poor

quality because farmers lack the ability to select seed and store it well. Poverty and food security also threaten the seed supply by sometimes forcing farmers to eat their saved seed. In addition to poor seed stocks, cultivation is not optimal. In many communities where women are mainly responsible for growing millets, few farmers are aware of improved cultivation technologies such as line sowing and fertilizing.

Production and management of millet crops

Millets are one of the most farmer friendly of crops. In fact in many communities, millets are considered the lazy farmer's crop! One really needs to do just two things: go to the field to broadcast seeds and then return after 3 months to harvest the grains. Millets require almost no inputs, grow even in extremely low fertility soils, don't need deep ploughing, can be sown with minimal tools or machines, need only one weeding (if at all). With timely good rains at the right times, the farmer can expect to reap a good harvest. Using some improved techniques and practices, farmers can get a decent harvest even when the rains are not up to par.

While the manner in which millets are managed or cropped differs depending on the species and environment in which they are grown, there are some general patterns that distinguish these crops. The small millets are often rain-fed crops growing in dryland farming conditions even though they respond well to irrigation. Because they grow well in warm weather and are dependent on rain, cropping is often associated with summer moisture systems like the South Asian monsoons. Fertilizers will increase yield, yet this is often not practiced. Field pests and diseases are not a concern, as is a need for weeding. Yet grain yield can be significant with minimal energy relative to the more traditional crops.

Pearl millet intercropping with pigeonpea in Andhra Pradesh

Maximum millet cultivation happens in the *kharif* period, i.e. during the monsoon season. In areas that receive more than 800mm of rains, many of the millets can be cultivated in the second season, i.e. as a Rabi crop (during the post monsoon, early winter months). And in some places with the right soil and geography, a few millets can even grow in the third season, during the dark days of winter, drawing on residual moisture in the soil and the dew that precipitates.

Millets are resistant to pest attacks. This is a characteristic that comes in very handy when planning a mixed crop farm cultivated using non pesticide management techniques. A few rows of millets separating rows of more susceptible leguminous crops are a common practice in farms in different parts of the world.

Water productivity, fertilizer use and plant protection requirements for millet crops

Crop	Water requirement to produce 1 kg yield (Litre)	Amount of fertilizer used (kg/ha)				No. of plant protection sprays
		Nitrogen	Phosphorus	Potassium	Total	
Rice	5000	75-100	50-75	20	145-195	4-7
Wheat	750	50-100	25-75	50	125-225	1-3
Maize	750	100-150	50-65	25-65	175-280	3-4
Sorghum	833	50-100	25-75	25-40	100-215	0-2
Pearl millet	667	50-100	25-50	25	100-175	0-1
Finger millet	1000	50-100	40-50	25-50	115-200	0-2
Other millets	1111	25	15	15	55	0

Millets are adapted to smallholder farmers' production systems: Most smallholder farmers, in India as elsewhere, are net food buyers, which means that increasing their disposable income is a crucial path to better nutrition. Enhancing the use of these neglected crops is thus a powerful way to contribute to nutrition security and at the same time increase the development of vulnerable people. Whereas millet crops grow quickly and complete the life cycle; some millets need 60-75 days to mature against 100-140 days for fine cereals. They adapt to a wide range of soil conditions, including poor and low fertility soils; easier to grow for poor farmers with difficult access to inputs. The small farmers can have large yield increases through improved farm conditions. Millets exhibit good response to sustainable application of fertilizers and water. The basket of millets ensure greater biodiversity on-farm, reduces pests and climate risks, improving farmers' overall resilience.

Millets make good contingency crops: These crops are possible alternative crops in the event of natural calamities like drought and flood. Most of the millets are short duration crops. Proso millet is the earliest among small millets maturing in 60

– 70 days. Foxtail, little and barnyard millets mature in 75 – 85 days. Pearl millet and sorghum mature in 80-120 days. Kodo and finger millets mature in 100- 130 days. Because of earliness, low water requirement and high drought tolerance, millets fit in contingency crop planning to mitigate drought. When favorable conditions return after alleviation of stress the small millets especially finger millet recuperate fast and grow luxuriantly.

Fonio farmers in West Africa have historically placed a high value on fonio not only for its nutritional properties, but also because of the way it fits into the ecosystem. The fonio belt str*etc.*es across the southern edge of the Sahel, the band of semi-arid territory between the Sahara desert and tropical Africa's lush forests.

The Sahel is hot and dry for most of the year, and most of the land is too sandy to support most crops. But drought-resistant fonio flourishes in that inhospitable setting. Its extensive roots help it draw water from deep underground, and it doesn't need much attention.

Fonio is important to rural West Africans because it's the first crop to be harvested in the "hungry season" – the end of the rainy season, when the previous year's harvest is gone but no other crops have come in yet. That's one reason that people still cultivate fonio despite how physically demanding it is to thresh, winnow and clean the tiny grain.

Millets are eco-friendly crops

These are called ecofriendly crops due to their lower requirement of water, chemicals and management interventions for raising the crops. Besides, some millets can come up in marginal lands and harsh weather conditions where no other crop can grow. In India, pearl millet comes up well in the hot weather of Rajasthan.

Sorghum yields a valuable crop in the receding moisture regimes of *rabi* environments of Karnataka and Maharashtra. Little millet, foxtail millet, brown top millet and barnyard millet are known to assure minimum yield even in case of failure of monsoon, thanks to their shorter life cycle.

Finger millet farmers realize good yields even with reduced rains and minimum inputs. As these crops are resilient to climate change and provide yield assurance despite environmental risks, they have sustained the onslaught of rice and wheat all these years, despite drastic reduction in cultivation. Another important byproduct of millet cultivation is fodder which is a main source of roughage for cattle in dryland ecosystem.

Climate resilient traits of millets

Pearl millet	80-95	Highly resilient to heat and drought, come up in very poor soils, but responsive to high input management
Sorghum	100-125	Drought tolerant, excellent recovery mechanism from stresses, highly adapted to wide range of soils, altitudes and temperatures, responsive to high input management
Finger millet	90-130	Moderately resistant to heat, drought and humidity, adapted to wide altitude range
Foxtail millet	70-120	Adapted to low rainfall, high altitude
Kodo millet	100-140	Long duration, but very hardy, needs little rainfall, comes up in very poor soils, good response to improved management
Barnyard millet	45-60	Very short duration, not limited by moisture, high altitude adapted
Little millet	70-110	Adapted to low rainfall and poor soils- famine food; withstand waterlogging to some extent
Proso millet	60-90	Short duration, low rainfall, high altitude adapted
Fonio	75-120	Shorter duration, Adapted to poorly fertile sandy and stony soils, low rainfall
Tef	60-120	Short duration, drought and flood tolerant, high altitude adapted, fit in diverse cropping systems
Brown top millet	60-80	Short duration, adapted to poor soils with less rainfall

Finger millet has the highest yield potential in moderate climates during rainy season

Millets are climate resilient crops: Millets being C4 crops, are efficient users of water and nutrients for growth. They are highly tolerant to warmer temperatures and to some extent to flooding. Their tolerance to salinity results in germination and seedling stages results in very good plant stand. As millets possess physiological mechanisms for rapid recovery from abiotic stresses like drought and heat, they are most promising sources for food during climate change.

In times of climate change millets are often the last crop standing and, thus, are a good risk management strategy for resource-poor marginal farmers.

Millets can withstand all ill effects of climate change except for possible higher ozone concentrations around urban zones. However, since millets are crops of low economic value and not perishable, are grown mostly in rural areas and would be least affected by increasing ozone levels in the local micro-climate.

Effects of changed climate on millet production - Sorghum and pearl millet

Parameter	Crop stages			
	Germination	Growth phase	Flowering and seed set	Maturity
Pearl millet and sorghum				
Temperature	Pollen viability, seed set and grain yield affected at very high temperature, heat tolerant genotypes available			
Rainfall	Required	Affected by poor rainfall; drought recovery mechanism is excellent		Not required
Salinity	Growth parameters and plant nutrition are affected, resistant genotypes available			
Higher CO_2	Not much affected (C_4 crops), small increments possible			
Flooding	Short periods of submergence are tolerated, sorghum vulnerable upto 30 days after sowing			

Utilization of Millets

Millet crops have multiple uses other than food. They are also useful as feed, fodder (dry and green), and industrial raw materials (including bioethanol from sweet stalk sorghum). Armoured with C4 photo-respiratory physiology, millets thrive better under moisture stress. The improved hybrids in sorghum and pearl millet yield 30-50% more than varieties. Sorghum and pearl mill*et al.*o the efficient producers of high biomass. Therefore, millets are "Resource Smart and Climate Smart" crops.

Food and Food industry use

Foods prepared from millets are several and differ from country to country and occasionally from region to region. In West Africa, the main food dishes from pearl millet vary by country. The stiff or thick porridges are the most popular, commonly consumed dishes in all the Sahelian countries across the region. The steam-cooked product 'Couscous' is more commonly consumed in the Francophone countries including Senegal, Mali, Guinea, Burkina Faso, Niger and Chad. The thin porridge 'bouillie' is also popular in these countries. Three countries among others have unique foods from pearl millet specific to them. In Nigeria and Niger the thin porridge 'Fourra' is very popular while 'Soungouf; 'Sankhal' and 'Araw' are very popular in Senegal.

In South Africa, sorghum meal is often eaten as a stiff porridge much like pap. It is called mabele in Northern Sotho and "brown porridge" in English. The porridge can be served with maswi - soured milk - or merogo - a mixture of boiled greens (much like collard greens or spinach). In Ethiopia, sorghum is fermented to make injera flatbread, and in Sudan it is fermented to make kisra. In Eastern Africa, pearl and finger millets are used to make beer. It is also an ingredient in Eastern European fermented drinks and porridges.

Flat breads from various cultures — including Mexican tortillas, Scottish oat cakes, Indian chapatti and roti, Chinese pao ping, American johnnycake and Ethiopian injera — are all descendants of biblical and Neolithic unleavened breads, and utilize pretty much the same balance of ingredients. Grains used vary with location, but many of these flat breads are still made with millet as they have been for thousands of years.

A young Ethiopian woman makes injera, a fermented bread made from the world's smallest grain.

(SOLAN GEMECHU/AFP/Getty Images)

In Ethiopia, white tef is more expensive and usually reserved for special occasions. Darker tef is considered more nutritious. It takes about 100 tef grains to match the size of one wheat kernel. All tef products are whole grain.

Fermentation of sprouted (germinated) millets results in significant increases in protein and starch digestibility. Fermented thick porridges are popular in Niger, Sudan and Southern Africa, while fermented thin porridges are commonly consumed in West Africa especially Nigeria and Ghana (ogi, koko, akamu, kunu) and East Africa mostly in Kenya and Uganda (uji) where souring (with lemon) is used instead of fermentation. In Nigeria and Ghana, stiff or thick porridges (tuwo) are not fermented, as done in francophone West African countries. Finger millet can be used to make porridge, bread, malt, animal feed, popped millet (like popcorn), Ethiopian liquor called arake, and even beer.

In China, millet porridge, bread, and other traditional foods are in vogue. Porridge is the most typical way to eat millet in China. During the colder months, vendors selling millet porridge can be found on many street corners in Beijing.

In the northern area of China, foxtail millet has been widely used as a nourishing gruel or soup for pregnant and nursing women, and has been applied as food therapy. The elderly are also advised to gobble down a bowl of millet congee every day before going to bed, to provide energy and help get a good night's rest.

For the life in between these stages, traditional Chinese medicine teaches that millet will help nourish yin, remove humidity, strengthen the spleen and stimulate the appetite, as well as nurture the liver and help lift blood production.

The grains of Japanese barnyard millet are a traditional food in the cold districts of Japan, especially in the Tohoku district where it is considered an important crop because of its ability to be stored for a long time as a food, as well as a seed with extended germination ability.

In India, millets are traditionally consumed as staple foods in the Indian diet. Some typical dishes of millets in India are Jowar (sorghum) roti in Maharashtra, parts of Karnataka, Madhya Pradesh, Uttar Pradesh and Rajasthan; bajra (pearl millet) roti in Punjab, Haryana, parts of Uttar Pradesh, Rajasthan and Tamil Nadu, and ragi (finger millet) mudde in Karnataka, parts of Tamil Nadu and Andhra Pradesh. Barnyard and little millet found place for niche use, as a bhagar food, consumed during fasting.

Kodo millet and little millet in Madhya Pradesh and Chhattisgarh, finger millet in Odisha, Andhra Pradesh and Uttarakhand, barnyard millet in Uttarakhand and Tamil Nadu, *etc.* are continuing to be under cultivation and consumption in the tribal areas.

Pearl millet is boiled to make an Indian porridge called Kambam Choru in Tamil Nadu. In many tribal areas, little millet is considered as a cash crop as it f*etc.*es much higher prices than rice. In Uttarakhand, finger millet is eaten as rotis, barnyard millet as paleu or chencha, a savoury porridge cooked in buttermilk. Zan is the most popular porridge recipe of Monpa tribes of Arunachal Pradesh made from finger millet and vegetables.

The dehusked grain of small millets is cooked like rice and eaten. In parts of South India, the grain is processed very similar to the parboiling of rice. Often, roti and porridge are made and consumed. It is also made into flour, used for making puddings or cakes. Another method is to cook cracked grains with vegetables and spices to prepare a food similar to curried rice. Fortification with lysine and heat processing improves protein quality and nutrition.

Foxtail millet grain is usually cooked whole like rice (millet rice) or made into meal. It is also consumed as stiff porridge called sargati, or as leavened bread known as roti, after the de-hulled grain has been milled into flour. Other food products are pudding, breads, cakes, chips, rolls, noodles, *etc.* More data on levels of consumption, commerce, *etc.* are not available and mostly it is localized in the production belts as well as in some niche market areas in the growing states. Sprouted grains are also eaten as vegetable in some regions.

Zan, Most popular porridge recipe of Monpa tribes of Arunachal Pradesh made from finger millet and vegetables.

In India, many other traditional foods from millets are made from popped flour mixed with sugar / jaggery / ghee / milk / butter milk and salt. Milled millet can be further processed towards various food uses such as flakes, quick food cereals, ready to eat snacks, supplementary foods, extrusion cooking, malt based products, weaning foods, and more importantly health foods.

Malting of finger millet for food uses is in practice from time immemorial in southern India. It has superior malting properties and the malt has acceptable taste, very good aroma and shelf life.

Traditional foods prepared from barnyard and other millets such as idli, dosa and muruku are very popular in parts of southern India. Sorghum and millets are used for developing various value added products like biscuits, sweets, vermicelli, ready mixes and multi-grain atta. In some regions minor millets remain cultivated only on a small scale but are culturally important for particular foods stuffs, such as ritual breads made from brown top millet in restricted districts of South India.

Sprouted millets

In America and Western Europe, proso millet has mostly been relegated to bird and livestock feed. However, interest in the grain has been growing, especially in gluten-free diets. In Europe and North America proso millet based dishes are used, though limited. The Bible refers to it in bread making, the Romans ate it as porridge. Many cuisines include millet, for example, porridge in China and Russia, and even beer in parts of Africa. Proso millet seed is also parched and consumed. In Eastern Europe, it is used for making porridge, bread and given as a feed for animals and fowls. In Europe, making brooms out of this crop is practiced. In USA, common millet is valued as a hog feed and used as a substitute for corn or sorghum in areas where neither would mature. In USSR, common millet is an important ingredient of poultry feed.

Because of its mild flavor, light color, gluten-free quality, and potential health benefits, proso millet has been receiving growing interest from the food industries in Europe and North America. Organic proso millet has a niche market because of its nutritional properties. In addition, the market for gluten-free food in the U.S. bread and grain industry is growing.

Thus, proso millet is gaining traction in the USA and European markets, especially in the gluten-free sector.

Tumut Broom Factory *(since 1946)*

The Tumut Broom Factory is the last original Millet Broom Factory in Australia. The Factory is located in Tumut, a small town in the Snowy Mountains.

The Biggest broom was produced by the factory in 1974 taking advantage of the extraordinary height of 1.4 metre attained by broom corn that year.

The biggest broom was 1.6 m tall (see picture)

In the cuisine of the Southern United States, sorghum syrup was used as a sweet condiment, much as maple syrup was used in the North, usually for biscuits, corn bread, pancakes, hot cereals or baked beans, but it is a rarity now. Sorghum sometimes is used for making tortillas (e.g., in Central America). In El Salvador, they sometimes use sorghum (maicillo) to make tortillas when there is not enough corn. In Arab cuisine, the unmilled grain of sorghum is cooked to make couscous, porridges, soups, and cakes. Many poor use it, along with other flours or starches, to make bread.

Tef is used to make injera flatbread in Ethiopia and other growing countries. Fonio is consumed as porridge. Fonio has different culinary roles depending on where you are in West Africa. In southern region of Senegal, it is eaten as rice or couscous. Malians most often pair it with peanuts to make a traditional staple called Djouka. People in Guinea, Burkina Faso, Nigeria, Benin and Togo make starchy fonio side dishes in the form of polenta or cakes. No matter how you cook it, fonio offers distinct nutritional benefits over other grains.

Millets in modern foods

Puffs can also be made from all millet grains and readily used as breakfast cereals. Investigations have proved that use of 100% millet in ready-to-eat breakfast

cereals would be feasible. Sorghum seeds can be popped in the same manner as popcorn, although the popped kernels are smaller than popcorn. Since several years sorghum has come into increasing use in homemade and commercial breads and cereals made specifically for the gluten-free diet in USA. Sorghum blended with wheat flour has been used over the last two decades to produce baked products, including yeast-leavened pan, hearth and flatbreads, cakes, cookies, and flour tortillas. Millet based malt drinks and malt cocoa-based weaning food and baby foods are popular in Nigeria. Hard endosperm sorghum is used extensively in south-east Asia for noodles.

Modern processing technologies provide more options to develop value added modern foods from millets. Processing interventions in post-harvest processing in millets include cleaning, grading, dehulling, *etc.* (primary processing) & semolina or suji, flaking, popping, extrusion, baking *etc.* (secondary) which lead to value-addition. Because millets are gluten free it does not make good leavened bread when used alone; however, it can be milled and combined with other flours to make delicious breads.

To increase the functional aspects of millets, processing such as parboiling, malting, flaking, popping, boiling, extrusion (hot and cold) are done. This results in the diversification and shift towards more convenient/ processed products of fine cereals like rice and wheat from the millets.

These processing interventions are easily achieved by retrofitting of the processing machinery. Multi-grain millet flour, flakes of sorghum and pearl millet, finger millet malt, sorghum rawa and pasta, millets based breakfast cereals, millets-based regional snacks and fast foods, *etc.* are the commercially available millets products in India both in retail and online. More extrusion based and bakery products are in the offing from different entrepreneurs. The 'organic' factor of millets is working in favour of uptake of these products in India, where gluten allergy issues are not so much present or ignored.

Absence of gluten makes millets unsuitable for the preparation of easy-to-handle pure-millet solid food products, particularly bakery or noodle products. However, they can be converted into liquid or semiliquid food products, such as porridge and other traditional household foods. Therefore, there is a need for innovative processing technologies to convert millet grains into liquid foods such as drinks of high nutritional quality and safety that can be consumed by large populations in rural and urban areas.

Malting and fermentation

Malting and fermentation processes result in malted and brewed products which are non-alcoholic and alcoholic depending on the desired needs. Millets are traditionally important grains used in brewing millet beer in some cultures, for instance by the Tao people of Orchid Island and in Taiwan.

Millet Wine (xiao mijiu) for sale in Wulai, Taiwan */Copyright Neil Wade*

It is also the base ingredient for the distilled liquor rakshi in Nepal and the indigenous alcoholic drink of the Sherpa, Tamang, Rai and Limbu people, Tongba in Eastern Nepal and Sikkim. In Balkan countries, especially Romania and Bulgaria, millets are used to prepare the fermented drink boza. In Eastern Europe, especially Poland and Hungary, millet is used to make fermented beverages and sweet and savory porridges called kasha.

Malted pearl millet and finger millet are used in the brewing of traditional opaque African beer in southern and eastern Africa. Finger millet makes the best quality malt used in both brewing industry and making of digestible nutritious foods. People in East Africa brew beer and a drink from millets or sorghum known as ajono. Sorghum beer is known by many different names in various countries across Africa, including Umqombothi (South Africa) burukuto (Nigeria), pombe (East Africa) and bil-bil (Cameroon). African sorghum beer brewed using grain sorghum undergoes lactic acid fermentation, as well as alcoholic fermentation.

The soaring success of Eagle brand sorghum based beer has created a high value for sorghum and transformed the lives of many African farmers In Eastern and Southern Africa, sorghum based lager beer is produced in Uganda, Tanzania, South Africa, Kenya and Zimbabwe. ***There are various breweries producing sorghum lager beer, such as Eagle brand in Tanzania. The anticipated demand for sorghum is expected to increase at an annual rate of 10-30% with more brewing plants using the indigenous sorghum and seeking supplies from smallholder farmers.***

Photo: *Alina Paul-Bossuet/Flickr/ICRISAT*

In China, sorghum is the most important ingredient for the production of distilled beverages, such as maotai and kaoliang wine. China's national drink 'baijiu', made with sorghum is considered beneficial to health and wellbeing. In Europe and USA, beer brewed with sorghum and rice is aimed at those with celiac disease, and it has low-carbohydrate content also makes it popular with health-minded drinkers. Foxtail millet is fermented to make vinegar and wine in China and to make beer in Russia and Myanmar.

Modern Millet Foods

Barnyard Flour kalajamun

Proso millet Shankarpala

Little millet Chinese fried rice

Ragi Upma pakodi

Pearl millet rusk

Sorghum chocolate

Ragi Bounty Bars

Sorghum Pani – Puri

Other uses

Sweet sorghum is used to a limited extent in producing sorghum syrup and 'jaggery' (raw sugar) in India and has recently gained importance in ethanol production for blending with petrol under national biofuel policy. Sweet stalked sorghum is used to produce bioethanol which can be blended with petrol to reduce the pollution as well as cost.

Sweet stalked sorghum has the highest biomass potential and suitable for ethanol production even from lignocellulosic biomass. This is a rainfed crop which produces grains as well

Sorghum straw (stem fibres) can also be made into excellent wallboard for house building, as well as biodegradable packaging. Since it does not accumulate static electricity, it is also used in packaging materials for sensitive electronic equipment. In West Africa, pearl millet is used to prepare thatch roofs. In the Arab countries, some varieties have been used for thatch, fencing, baskets, brushes and brooms, and stalks have been used as fuel.

Millets for animal feed and fodder

Sorghum grain is one of the major ingredients in swine, poultry and cattle feed in the western hemisphere, China and Australia. Sorghum is also grown for forage; in northern India it is very common and fed to animals fresh or as silage or hay. In the Arab world, the seeds and stalks of sorghum are fed to cattle and poultry.

Millets for green forage

Millets are grown for green forage in USA, India, South America, Middle East and Egypt. In India, in regions with assured irrigation, exclusive forage producing sorghum and pearl millet forage varieties and hybrids are grown which produce superior quality fodder for the feeding livestock. Many multi-cut type hybrids are available in these crops which ensure continuous supply of green fodder during *kharif* and summer seasons. The interspecific Pearl millet × Napier grass hybrids (popular as Napier bajra hybrid in India) is a perennial forage crop and is popular in dairy farms throughout the country. Pearl millet uses less water per unit of forage production, tolerates both lower and higher soil pH and higher aluminum concentration, and is rich in minerals as compared to sorghum. However, sorghum has a wider range of adaptability and is more widely grown.

Sorghum forage quality is better than that of other millets and next only to maize. Low-lignin brown mid-rib varieties of sorghum forage quality is equivalent to that of forage maize in USA. Per day biomass production potential is the highest in pearl millet x Napier hybrids followed by forage sorghum cultivars. They are also more water efficient compared to forage maize.

Sorghum is the major supplier of green and dry fodder in India and its role becomes important during the lean period of winter and summer months. About 20 to 60% of dry fodder supply in semi-arid area is dependent on sorghum. It is estimated that sorghum fodder constitutes 20-45% of the total dry weight of feed of dairy animals during normal seasons and up to 60% during the lean summer and winter seasons. The importance of sorghum is more pronounced in areas where livestock enterprise is one of the important livelihood strategies of people.

Forage sorghum in India *Inset: low lignin high digestibility variety*

Forage sorghum is cultivated in about 3.0 million ha area in India each year. Forage sorghums are principally cultivated in Punjab, Haryana, Delhi, western and central Uttar Pradesh and adjoining areas of Madhya Pradesh. In these states, it is grown during *kharif* and summer seasons, either as single-cut (mostly in *kharif*, as rainfed) or as a multi-cut (summer and *kharif*) irrigated forage crop. Intensive cropping, short growing season, poor growth of perennial grasses during winter, nutritional quality and the need for continuous supply of green fodder created demand for forage sorghum in northern India.

Stover from millet crops

The farm communities in the semi-arid and arid regions of the country are dependent on crop residues as a major form of roughages for cattle since they neither have the luxuries of green fodder from irrigated forage crop nor can afford to sacrifice the farm area for a dedicated one-time green forage. As the millets are the major cereals of dryland, they form an important source of stover (millet plants left after harvesting the ear head) for the livestock of these regions. Annually, millets account for 11% of the 30 million tones crop residues produced in India. The decision of the farmer to select the crop and variety are greatly influenced by the ability of the crop/variety to meet their fodder requirements from stover, although stovers are poor in nutrition compared to green fodder.

Stovers contain less of protein, total digestible nutrients and less palatable than green forages. Finger millet, kodo millet and little millet may also be used as sole forage crops as they provide good quality forage. Finger millet straw is used in many parts of the country for feeding all categories of animals, such as working animals, milch animals and dry animals. This serves as an important source of dry fodder which is a must in the daily ration at least in small quantities. It is said that for all kinds of cattle, finger millet straw is superior to that of rice.

Barnyard millet has an important place in dairy due to high palatability of its fodder. Its fodder can also be used for making hay or silage. Proso millet green plants and tef are good fodders for cattle and horses, also used as hay. However, forage from proso millet, foxtail millet are of lower quality. Green fodder from most of these millets can also be made into silage and used during off-season feeding.

Research on Millets- Indian Scenario

But, the launching of coordinated crop improvement programs during late 1950s and 60s has contributed significantly by way of developing new superior varieties and concomitant production and protection technologies in all millets. The release of these varieties and production packages for general cultivation has helped in five-fold increase in grain production from 50 million to 250 million tons in the country. It is generally seen that this increase has largely come from two major crops –rice and wheat- and less from dry land crops such as millets and more so from small millets.

Research efforts on millet crops in India have been in progress since the beginning of the 20 the century. Research on millets including sorghum in India began in Pre-Independence period in some centres such as at Agricultural College, Coimbatore during 1920s. Indian Council for Agricultural Research (ICAR) carried on the research in millets after independence with the establishment of coordinated programmes involving State Agricultural Universities (SAUs) and ICAR research institutes.

The first finger millet variety released in the country was H 22 as early as 1918 in Karnataka developed by Leslie C. Coleman by pure line selections in indigenous varieties at Hebbal farm, Bangalore. Interest in finger millet improvement got a fillip in Karnataka during 1950-60 when hybridization technique was established and several new varieties were released.

The significant contributions of finger millet breeder CH Lakshmanaiah came about when he started hybridization work to create new recombinant varieties by crossing Indian varieties with African ecotypes during 1964 that led to development of new "Indaf" varieties with substantially more yield potential.

Similarly, many varieties were released in other small millets also in many states. This included little millet variety Co 1 (1954); foxtail millet varieties Co1, Co 2, Co 3 (1943), H1, H2 (1948), T 4 (1949); kodo millet varieties PLR 1(1942), T 2 (1949), Co 1 (1953); proso millet variety Co 1 (1954) and barnyard millet varieties T 46, T 25 (1949). During fifties, with food production remaining stagnant and with raising population the importance of millet crops to Indian agriculture started gaining recognition, as they formed the important constituents of dry land agriculture.

Dr. Ch. Lakshmanaiah, the pioneer finger millet breeder is well known as 'ragi' Lakshmanaiah

Establishment of ICAR-Indian Institute of Millets Research and AICRP on Sorghum

In 1956, a project for Intensification of Regional Research on Cotton, Oilseed and Millets (PIRRCOM) was initiated in order to intensify research on these crops. The PIRRCOM was located at 17 different centres spread throughout the country some of which focused on sorghum and pearl millet research. All-India Coordinated Research Project on Sorghum (AICRP) was established in December, 1969 with the main objective of conducting research on grain and forage sorghum improvement with a dozen collaborating centres across the country. The IARI regional station at Hyderabad was reframed as the National Research Center for Sorghum (NRCS) in 1987 and the AICSIP was integrated with this centre. NRCS got upgraded as Directorate of Sorghum Research (DSR) during 2009 and expanded in 2015 as Indian Institute of Millets Research (IIMR) to conduct research on all millet crops.

With the release of CSH 1, the first commercial sorghum hybrid in 1964 pioneered by Dr. NGP Rao, sorghum became the second crop after maize in developing high yielding hybrids using cytoplasmic-genetic male sterility system. After CSH 1, 25 more hybrids at central level and a few at state levels were released as adapted to specific regions. These hybrids played a major role in pushing up productivity and production, particularly in the case of *kharif* sorghum.

Dr. NGP Rao, developed the first sorghum hybrid in India

Among the *kharif* hybrids CSH 1, CSH 5, CSH 6, CSH 9, CSH 14 and CSH 16 need special mention as CSH 5 and CSH 6 had a yield potential of 34 q/ha which was raised to 40 q/ha in CSH 9 and further raised to 41.0 q/ha in CSH 16, CSH 23, CSH 25 and CSH 30 with distinct superiority in grain and fodder quality. NGP Rao was the pioneer sorghum breeder due to whose efforts Indian sorghum productivity improved drastically. He is at times referred to as the 'Father of Hybrid Sorghum' in India. Due to his efforts sorghum hybrids, CSH1 CSH5 and CSH9 became very popular and were cultivated in over 8 to 10 million hectares. The growth rates of sorghum during the 1970s and 1980s were comparable to irrigated wheat and rice.

High yielding varieties CSV 1 to CSV 30 at central level and many more at states level were released. Some of these varieties are dual-purpose type. By and large, varieties were less acceptable to farmers in the early decades. Better preference was for the later dual-purpose varieties such as CSV 10, CSV 13, SPV 462, CSV 15, CSV 20, CSV 23 and CSV 27 in some pockets. The adoption of improved cultivars, unfortunately encountered some limitations. The reduced maturity duration of the HYVs led to its high vulne*rabi*lity to grain mold damage during *kharif*. Building reasonable resistance against grain mold is difficult. These biological limitations seriously restricted the economic advantage of their high yield. The government policies on production, pricing, procurement and distribution of cereals favoured fine cereals and placed coarse grains such as sorghum at a disadvantageous position.

Improvement of *rabi* sorghum did not receive as much importance as *kharif* sorghum until the nineties. Six hybrids and five varieties were hitherto centrally released for *rabi*. In *rabi* sorghum, the fodder yield is even more important than *kharif* sorghum. From this point of view, a progressive success was achieved from the first *rabi* hybrid CSH 7R to the latest hybrid CSH 19R. Unlike the *kharif* cultivars, higher levels of resistance against major pest (shootfly) and disease (charcoal rot), stringent maturity duration requirements to suit different receding soil moisture regimes and adequate levels of thermo-insensitivity are essential in *rabi* cultivars for better adaptability. Grain quality is also as much important as the grain yield, with quality benchmark being Maldandi (M 35-1). In adaptability criteria such as shoot fly resistance as well as the grain quality aspects, the varieties are superior to hybrids. The three *rabi* varieties released, CSV 8R, CSV 14R, CSV 18 and Swathi, were better received than the *rabi* hybrids such as CSH 7R and CSH 8R. However, the recently developed hybrids CSH 13 R, CSH 15R and CSH 19R are more productive, but the acceptability among farmers is not high as they do not want to invest on hybrid seeds every season during *rabi* (dry season) without irrigation. However, the new range of soil depth specific varieties like Phule Anuradha, Phule Revathi have achieved niche area with greater productivity and quality in relation to Maldandi.

Launch of All India Coordinated Pearl Millet Improvement Project (AICPMIP)

All India Coordinated Millet Improvement Project (AICMIP) was established in the year 1965. Pearl millet was separated from the rest of the millet crops and the All India Coordinated Pearl Millet Improvement Project (AICPMIP) was established in 1985 with its headquarters at Pune as an independent coordinated project. In 1995, the ICAR shifted the headquarters of AICPMIP to Jodhpur in the state of Rajasthan, the state which occupies nearly half of pearl millet area of the country.

The All India Coordinated Pearl Millet Improvement Project (AICPMIP) has played a pioneering role in developing a diverse range of improved breeding lines and parental lines of hybrids. These lines have been used extensively to develop and commercialize a large number of hybrids. These hybrids are currently cultivated on approx. 50% of the total pearl millet area of 9-10 m ha.

Pearl millet hybrids maturing in 80-85 days, when cultivated as an irrigated rains/ summer season crop in parts of Rajasthan, Gujarat and Uttar Pradesh, have been reported to give as high as 4000-5000 kg/ha of grain yield.

Establishment of All India Coordinated Millets Improvement Project (AICMIP)

Millets in general started receiving with attention with the launching of All India Coordinated Millets Improvement Project (AICMIP) in 1969. In this project small millets also started receiving some attention at a selected few centres. Small millets improvement received the major boost during 1978-79 with the establishment of five crops specific lead research centres in the country under IDRC assistance which continued till 1985. The "All India Coordinated Small Millets Improvement Project" (AICSMIP) was established in the year 1986 with headquarters at The University of Agricultural Sciences, Bangalore. The centres that were functioning under IDRC project became part of AICSMIP and many more were added.

Small millets are known for their suitability to dry land areas, hill and tribal agriculture and contribute to food and nutritional security of the disadvantaged regions.

With the inception of separate AICRP, research on small millets has been getting focused attention for developing varieties and other agro production and protection technologies suitable to different regions. The research in the project is focused to state / regional needs from the point of developing appropriate varietal and agro production technology for maximizing production / productivity.

Popular varieties of millets such as blast resistant 'GPU 28' in finger millet, short duration 'Sooryanandi' in foxtail millet and 'TNAU 86' in kodo millet, high

yielding 'OLM 217' in little millet, and 'CO(PV) 5' in proso millet have been released in recent years.

State Agricultural Universities have significantly contributed to millets R&D in those states where millets are major crops. All of them had the support of ICAR coming through AICRP centres as well.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), established in 1973 in India, contributed substantially to Indian and African agriculture of sorghum and millets, with development of improved breeding material, trait-specific hybrid parents, facilitation of international exchange of millets germplasm, strategic production technology research, collaboration with private industry, and research capacity development.

With several research centres in African countries, ICRISAT has significantly supported African agriculture of sorghum, pearl millet and finger millet, among others. Recently finger millet has been added as mandate crop of ICRISAT. The smart food campaign is a new initiative of this institute for popularizing millet products.

ICRISAT's high-Iron pearl millet variety ICTP 8203Fe was released as Dhanshakti in Maharashtra State

ICAR institutes such as Vivekananda Parvathiya Krishi Anusandhan Samsthan, Almora, National Dairy Research Institute centre at Bangalore, Indian Grassland and Fodder Research Institute, Jhansi, Central Arid Zone Research Institute, Jodhpur, Central Research Institute for Dryland Agriculture, Hyderabad, and others also supported millets related research. Central Institute of Agricultural Engineering, Bhopal, has developed a dehuller for small millets. Significant contributions in millets research have made by other institutions outside the National Agricultural Research System as well. Notable among them are Pearl Millet Downy Mildew Research Lab in the University of Mysore, National Institute of Nutrition, Hyderabad, Central Food Technology Research Institute, Mysore and many regional universities.

Summary of developments in millets production in India in the R&D era

- Sharp decline (50-60%) in area of millets after green revolution.
- Highest decline of area in small millets (83%) followed by sorghum (57%), finger millet (40%) with least decline under pearl millet (23%). Pearl millet has now occupied first position among millet crops in the country.
- Despite surrender of almost 50% area, the millet production has increased from 14.07 to 18.62 million tons, which is a positive development in this sector.
- Development and adoption of improved varieties/hybrids have played a significant role in productivity improvement of these crops.
- Due to low productivity, declining demand, small millets could not compete with the other crops with better productivity and demand resulting into the decline of area and production of these crops.
- The productivity gain has helped in meeting the demand of millet grains and utilization of millet areas for high value crops like soybean, maize, cotton, *etc.*
- More concerted efforts and support both in terms of research and development is needed for sustaining the production of small millets, which provides lively hood to large number of tribal farmers.
- Private entrepreneurs have contributed significantly to improved hybrid development and their commercialization in pearl millet, forage and grain sorghum, including in other countries and exports

State-wise highlights

- The State wise trend also confirm the similar decline of area (50%).
- Highest decline in area has been in undivided Andhra Pradesh (91%) followed by Tamil Nadu (79%), Madhya Pradesh including Chhattisgarh and Gujarat (69%).

- The area in Andhra Pradesh has been diverted to cotton, maize, soybean and rice, whereas in Madhya Pradesh and Maharashtra larger area has been diverted to soybean.
- Rajasthan is the only State where area of millets is maintained. It may be because of agro-climatic limitations, farmers did not find better option than pearl millet.

Technological developments

- Millets are pioneer as far as utilization of hybrid technology is concerned.CSH-1 (sorghum) and HB-1 (pearl millet) were the first hybrids released during 1964 and 1965.
- High yield potential up to 5950 Kg/ha in pearl millet, 7000 Kg/ha in sorghum, 5000 kg in finger millet and 2648 Kg/ha in small millets have been recorded in farmers' production by the adoption of improved technologies.
- Release of > 80 hybrids of sorghum (26) and pearl millet (70) and > 100 HYVs of millet crops during last 15 years indicates availability of good genetic variability. At least half of these are yet to reach to the farmers' field.
- Value added products of millets have started entering the mainstream urban food chain due to demand created by health conscious consumers

Ongoing R&D efforts

AICRPs on Small millets, sorghum and pearl millet have been involved in developing improved technologies for sustainable production of millet crops. Activities of IIMR and respective AICRPs to support beneficial farming of millets are as below.

- Enhancing the productivity of millets through evolving of new varieties. Production technologies have been developed for all small millets. The productivity of finger millet, pearl millet, sorghum and foxtail millet doubled during the past 40 years. Varieties with high yield potential have also been developed in barnyard millet, kodo millet, little millet and proso millet at national and state levels.
- Varieties suitable for different climatic conditions and superior in different nutrients have also been developed.
- Popularizing the millets as nutri-cereals so that the demand for millet based foods increases and farmers realize beneficial value for their produce. In this regard, IIMR has taken up value addition technology development, dissemination of the technologies by training entrepreneurs, media campaign about health benefits of millets, making ready-to-cook (RTC) and ready-to-eat (RTE) millet based foods available through licensing of manufacturing technologies.

- IIMR and AICRPs are regularly taking up Front line Demonstrations in farmers' fields to demonstrate the benefits of latest varieties and production technologies. Farmer groups are regularly trained in production technologies, post-harvest processing and value addition technologies.
- Machinery development for post-harvest processing of millets is underway to enable farm-gate processing that would result in higher returns for the farmer for the produce.
- Multi-dimensional initiatives to work with different stakeholders for the promotion of millets to enhance the demand in order to enhance demand and add value for the farmers' produce.

The Fall and Rise of Millets

Millets are the eco-friendly crops that provide both food and nutritional security. Nevertheless, there has been a rapid decline in consumption and cultivation of millets in the country. Millet crops perform well in marginal (dryland) environments and are superior in nutritional properties with high micronutrient and dietary fibre content, and low glycemic indices. Millets are the only viable option in the dryland condition since they require minimum application of irrigation and can withstand adverse weather conditions. Millets are traditionally cultivated in near- organic manner as there are no heavy-damaging pests and diseases exist for millets. Millets also provide decent yield in rainfed conditions. Presently most of the organic producers and exporters in the country have millets in their portfolio, According to the data from APEDA, 17% organic exports during 2015-16 comprised of cereals and millets.

The millets have always been regarded as less important due to which not much efforts have gone into improving their productivity as crops, utilization as important staple foods, and processing and food technology development. As a result, the cultivation of millets is relegated to the poorer soils and harsher climates, unable to realize the potential of improved varieties. Millet consumption as staple food is confined to the elderly people who vouch for the goodness of millets and tribal communities for whom millets are a part of their life and diet. Even today, millets contribute to 7% of food basket, catering to the food and nutritional security of the poorest of the poor.

Upscaling of millets production and establishment of supply chains through organized processing centres /hubs near growing regions has not happened. The challenges of reducing losses during processing, enhancing the shelf life of processed millets, ease of cooking, *etc.* have not been addressed at all though they are known for a very long time.

Revitalizing millets into mainstream dryland agriculture and diversifying the food basket is important for sustaining the food, nutritional security of consumers and livelihood security of the rural households. For achieving this, the major challenges are to deliver millet based technologies which are sustainable and market oriented. This can be achieved through reconsideration of millets research in terms of present and future demand, resolving specific production constraints thereby improving productivity, improved agronomic practices, development

of value addition and processing technologies, marketing strategies and policy measures that would generate more income and employment generation to the farmers without sacrificing overall goal of attaining sustainable food and nutritional security. Scientific and technological interventions involving convergence of efforts of agricultural and food scientists, policy makers and media is needed to revalorize millets for attaining food and nutritional security.

Millets have been considered 'not important' or inferior

Millets have received far less research than the "big" cereals (rice, wheat, and barley). Indeed statistics on millet production are very poor, as they are grouped as "minor cereals" in most national and FAO statistics. This is, at least in part, the product of a historical European bias against millets, especially among the former colonial powers of Northern and Western Europe, where millet cultivation is negligible. These cereals were undervalued and under-researched in the colonial period which set an unfortunate precedent for modern governmental and nongovernmental agricultural organizations. The eclipse of a prior 'millet hegemony' is difficult to trace because the beginnings of this process lie sometime in the Early Historic period (c. 300 BC- 1000 AD), when both textual and archaeological data are scanty.

In ancient India, Sushruta in 500-600 BC classified the millets known then into 'kudhanya varga', the inferior grains. Probable reason for these aspersions perhaps is that some of them have a rather strong taste. When people are given free choice, they seem to prefer cereals such as wheat and rice which are bland and mild to taste. It was ironical that these millets have now been proved nutritious and beneficial for health. Also, these were the same grains that helped sustaining the agriculture and thereby civilization when climate changed to decreasing rainfall during the late-Harappan period.

There are several "lost" or disappearing millets, cultivated in much localized areas or documented archaeologically only. This includes the recently "rediscovered" *Spodiopogon formosanum* of Taiwan, the now relict brown top millet of South India, the local domesticate "raishan" (*Digitaria cruciata*) of the Khasi Hills in northeast India, the black fonio (*Brachiaria deflexa*) and iburu (*Digitaria iburu*) of West Africa, the Sonoran millet of the American Southwest (*Panicum sonorum*), and the no longer cultivated crabgrass millet of Southeastern Europe (*Digitaria sanguinalis*) referred to in historical sources ranging from late Roman times to the nineteenth century.

It is rather unfortunate that investment in research to improve food nutritional quality which can contribute most meaningfully to prevention of chronic disease is often overlooked by most governments and other funding agencies in favor of

seeking treatments for diseases once they occur. For example, the US government invests billions of dollars every year on biomedical research aimed at discovering causes and treatments for disease through National Institute of Health, National Science Foundation, among others. By comparison, the total amount of money that goes into prevention research including healthy food options is a drop in the ocean.

Fall of millets in India

The withdrawal of millets from Indian food basket began from late 1960s when rice and wheat became available in more quantities at an affordable price. With the advent of high yielding varieties of rice and wheat in the process of green revolution during the 1960s, the cultivation of these crops became more profitable and more area came under them, thanks to the novel genes introduced from Philippines and Mexico. No such productivity-enhancing genes were available for millets. While wheat spread to non-conventional areas of eastern and southern India, rice cultivation spread to western India. This was further supported by the availability of fertilizers with subsidy, more area coming under irrigation due to dams, and so on. Later on, the government schemes to provide rice and wheat at highly subsidized prices ensured faster disappearance of millets from all kitchens.

Even convenience of cooking and tastes mattered. Making rotis from millets has always been a tougher task compared to making wheat roti, being gluten-free. The polished rice was tasting better to consume, than the fibre and anti-oxidant-rich millets, thus rice from millets were less preferred over white rice.

The social apathy for millets resulted in the shifting of food habits. In spite of these, due to the development of hybrids in sorghum and pearl millet, productivity was more than doubled and they could hold some ground in cultivation. Exotic crosses also led to high yielding varieties of finger millet which sustained the production due to increased income to farmers. Moreover, fodder is an important byproduct of millets cultivation, an invaluable livestock feed in dryland ago-ecologies. Millets production in the country sustained the levels due to this productivity increase though the cultivated area under these crops came down drastically.

Most of the dryland farmers greatly reduced the area under millets due to lower demand and less monetary returns. It is owing to the hardiness of these millets that they still find place in good number of farms, though in smaller patches than before.

There are certain marginal areas and harsh climates where nothing else can be grown except millets. Further, these crops also provide superior quality fodder, especially in lean season, and thus find a place in the mid-sized to large farms with livestock.

Area under millets gradually reduced till late 1980s and rapidly thereafter. The rapid decline after 1980s can be attributed to area expansion under the new crop soybean which was highly suitable for cultivation in drylands and was also profitable. More area also came under irrigation due to dams, and state incentives for ground water exploitation. During the last 15-20 years millets gave up substantial area to cotton and maize.

Africa: Even in Africa, despite its importance of finger millet as a food crop, many policy makers in countries that grow finger millet generally regard it as a poor person's crop, and the scientific community has largely ignored it. Many farmers are giving up growing the labor intensive finger millet in favor of maize, sorghum, and cassava.

In South Africa, millets are looked upon as raw material for alcoholic products such as beer and hence even food purpose millets and their products are taxed more.

One hurdle in finger millet production is that it is a labor intensive crop. In Africa, the crop is most often harvested by hand and individual heads are cut off with a knife. The small size of the seeds makes it difficult to handle, and it takes a lot of skill and effort to make it into flour, especially by hand. Weeding is also problematic because the dominant weed in African finger millet fields is a relative of the crop and hard to discern from finger millet itself.

Reasons for loss of area and production

Highly subsidized rice schemes and increase in irrigation in certain southern states have resulted in a shift towards rice both in terms of cultivation and consumption. Other factors like convenience of cooking, difficulties in processing of millets on a large scale and relatively lower productivity giving economic advantage to the cultivation of fine cereals are also responsible for the shift from millets to cereals. Thus, both supply led factor such as subsidized input supply and demand led factors such as Government policy to supply fine cereals at subsidized prices, output incentives, *etc.*, have resulted in lowering of consumption demand and in turn decline in acreage under millets.

Apart from nutritional disadvantage of losing millets from the diet, extensive cultivation of fine cereals using ground water in arid areas is threatening water security in the country.

Reasons for decline in millets area and consumption in India

Demand side factors	Supply side factors
1. Rapid urbanization	1. Increasing marginalized cultivation
2. Changing consumer tastes and preferences due to rising per capita incomes	2. Low profitability-low remuneration for millets vis-à-vis competing crops
3. Government policies favoring other crops such as output price incentives and input subsidies	3. More remunerative crop alternatives in *kharif* competing with millets in question
4. Supply of PDS rice and wheat at cheaper price introduced in non-traditional areas of fine cereals.	4. Decline in production and quality (as in *kharif* sorghum because of poor quality of grains due to blackening of grains, f*etc.*ing low price to the farmers)
5. Poor social status and inconvenience in their preparation (especially sorghum) and	5. Lack of incentives for millet production and
6. Lower shelf-life of milled grain and flour of millets.	6. Development of better irrigation infrastructure / options as in small millets.

Millets are rising again

Since the 1970s millet has been gaining popularity in Western Europe and North America as a nutritious, quick cooking and delicious whole grain. Another reason for millet's recent resurgence is that it is gluten free and therefore ideal for those with sensitivity to modern wheat or other grains that contain gluten. Over the last decade, gluten-free food has gone from being ridiculed for its lacklustre taste and texture to a way of life for health-conscious consumers in developed countries. There's been somewhat of a finger millet resurgence in Africa. In Kenya, the grain sells at higher price than that of sorghum and maize. In Uganda, more area is producing finger millet.

R&D efforts and policy push for millets in India

With pioneering efforts of ICAR to promote value chains across commodities, IIMR led consortium came out with a pilot scale successful value chain model on sorghum and millets which was operated for three consecutive years, a focused millet development and promotion programme. It paved way to the Ministry of Agriculture, Government of India, to initiate Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP) in April, 2011 with an outlay of Rs 300 Crores which was for launched across 10 millet growing states. It has seen some success for the up-lift of the neglected millet crops in the focused ten states. But, the processing interventions did not have the same success due to teething problems that were not properly addressed. In 2015-16 the programme has been subsumed into National Food Security Mission (NFSM) and millets lost their focus and merged under coarse cereals component. However the positive effects of the INSIMP as well as the efforts of many states has led to a credible millet promotion in the states of Karnataka, Tamil Nadu, Andhra Pradesh and Telangana, where it is estimated that about Rs. 300 crores

business is happening in form of small startups emerging into various millets value chain aspects such as supply chain management, fabrication of millet processing machinery, development and production of various value added healthy products and their promotion *etc.* Hundreds of brands are now into the millet space.

Now the awareness about goodness of millets is spreading to the educated strata, mainly made of middle and upper classes, and thus millets are back in grocery shops, part of retailing and online, and invariably make a good part of portfolio in organic food outlets.

The demand generated from the knowledgeable urban and semi-urban consumers that is driving the availability of millets in these places. However, backward integration still remains a challenge and a major concern is that the profit due to demand generation through value addition has not percolated down to the farmers.

Therefore crop area remains either stagnant or declined. However at this juncture there is a great need to understand the current situation and debate the future prospects of millets.

Buoyed by all these developments, recently the Government of India has taken the plunge to include millets in the public distribution system (PDS). Also a sub-mission on "nutri-cereals" is contemplated for the next two years under NFSM, exclusively for millets. Considering the importance of millets for the farmer, the consumer and the environment, the Government of India along with other country governments has urged the United Nations to declare a year as the International Year of Millets. This will go a long way in popularizing millets which would benefit future generations of farmers as well as consumers.

The government of Tamil Nadu has initiated millet mission while Karnataka government promotes finger millet and small millets, the government of Andhra Pradesh has launched millet action plan for the next three years.

The Kerala government has initiated millet village project during 2017 to encourage the tribals to return to millet cultivation to ensure their nutritional security and well-being.

Tamil Nadu took a recent step to increase millet cultivation in the fallow lands. Maharashtra, Telangana and Tamil Nadu have done pilot scale programmes on inclusion of millets in mid-day meal (MDM) in schools.

Policy and incentive support for creating farmer producer organizations, farm gate warehouse and processing in village clusters, linking farmers to the value

chains of both nutri-grains and nutri-fodder and the platform of e-NAM can enable better price and incentivize farmers to produce more of millets adopting improved and sustainable technologies. That would enable the nation to produce surplus of nutri-cereals to confer cost efficient and environment friendly food and nutritional security, once all the policy initiatives are fulfilled and comprehensive millets policy is in place.

Since, millets are linked with health and nutrition, which is a vast area and cannot be solved by the Government alone, hence role of all stake holders including private sector is vital. Many governments and organizations are quick to advise the public on what they ought to eat to stay healthy. However, people will not be convinced to eat much of anything just because it is supposedly 'good for you.' A major obstacle with many potentially healthy products is that they do not meet consumer quality expectations. Addressing this more effectively will go a long way in ensuring food is a primary vehicle to prevent disease. All the bottle necks in processing and value addition to develop acceptable and attractive food products is imperative. Delectable foods and easy to cook products which are enjoyed by all age groups need to be in place to sustain the good work of promoting healthy foods like millets.

Mission Millet in Kerala: Honourable Agriculture Minister V.S. Sunil Kumar ploughing a field for millet cultivation at Attappady

Millets in Karnataka

With no exception to world and national trends, millets have been under pressure to vacate cultivable lands to other 'remunerative' crops in Karnataka as well, since decades. However, finger millet has been doing well with only 30% decrease in area, thanks to the finger millet-based food culture of central and south Karnataka.

Millets	1961-66		2014-15		Per cent decrease in area	Per cent increase in yield
	Area (lakh ha)	Productivity (kg/ha)	Area (lakh ha)	Productivity (kg/ha)		
Sorghum	29.41	454	10.54	1061	64.4	233.7
Pearl millet	4.85	244	2.34	1061	51.7	434.8
Finger millet	10.22	715	7.08	1834	30.7	256.5
Small millets	4.19	331	0.12	524	97.2	158.3

There was decrease in area of all these millet crops from 1961-66 to 2014-15. The decrease was 64.4% in sorghum, 51.7% in pearl millet, 30.7% in finger millet and it was a drastic reduction of 97% in small millets. However, the productivity in sorghum increased by 234% in sorghum, 435% in pearl millet, 257% in finger millet and 158% in small millets. Despite reduction in area, production of theses millets was maintained and the demands were met. The shrinking in area was hugely for the state's traditional crops – the millets finger millet in the south and sorghum in the north. The total area under millet cultivation in Karnataka was 1.8 million hectares during 2016-17.

Area, production and yield of millets in Karnataka (2014-15)

Millet crop	Area (000 ha)	Production (000 ton)	Yield (kg/ha)	Per cent contribution to millets production	Per cent contribution to national production	Yield difference from national average (%)
Pearl millet	234.29	248.60	1061	9.1	2.7	-15.5
Sorghum	1046.05	1173.30	1122	42.9	21.5	26.9
Finger millet	708.45	1299.14	1834	47.5	63.0	7.5
Small millets	11.92	11.92	524	0.4	3.1	-20.0
Total	2000.71	2732.96				

Today, Karnataka is one of the leading producers and consumers of millets in the country, finger millet, sorghum and pearl millet being the main crops. It also stands at the top of the market with a huge demand for millets. The near extinct crop brown top millet suddenly got a lease of life and is in huge demand.

Bengaluru- the millets food hub

With a rich history of millets cultivation consumption and continuing the legacy in all its glory despite the decreasing importance of millets in the previous decades, Bengaluru is the natural hub where 'millet rising' is happening. A health-conscious new generation consumer strata, multiple generations of locals who cherish not just millets but 'variety' cuisines, hundreds of entrepreneurs who add value to the traditional business and showcase the 'siridhanya' for health and goodness, extending awareness and business reach in the era of communication explosion through social media – all transformed the Kempegowda's capital into the most happening place for millets. Several millets and organic food serving restaurants are coming up in Bengaluru. Millet pizzas, millet ice creams, burgers, breads and an array of western and regional snacks have become extremely popular with foodies.

Source: *The Economic Times*

With the incessant and earnest interest of the Karnataka's Honorable Agriculture Minister Mr. Krishna Byre Gowda in promoting millets for the cause of farmers and a healthy society, millets are going places. The state agricultural department has been organizing organic and millet fairs –'Siridhanya mela's in other towns of Karnataka on a regular basis, incentivizing millet cultivation, procuring millets and organizing for PDS.

The civil society groups and corporate social responsibility wings have been attracted by the initiative of the state government and have taken plunge for the promotion of millets which are getting recognition as smart foods.

Karnataka at the forefront of promoting millets

To revive the production and consumption of millets, the Karnataka government has been providing subsidy on seeds and higher bonus price for government procurement, leaving more money with the millet farmer to ensure profitability. The millets have been also introduced in PDS in a limited scale. The Karnataka government has also been organizing awareness creation and promotion campaigns to sensitize all the stake holders, including healthcare providers,

nutritionists, chefs, hoteliers, students, *etc.* in various places in the Bengaluru city as well as outside. The National Organic and Millets Fair organized in 2017 brought out the much needed common platform and interactive interface for all the stake holders in millet production and consumption, especially connecting farmers to markets.

Hon'ble Minister for Agriculture, GoK, Sri Krishna Byre Gowda inaugurating the National Trade Fair – Organics and Millets-2017' during April 28 – 30, 2017

The national fair also assured farmers, consumers and entrepreneurs that they are all the part of millets revolution and are here for a long haul, for the state is with them.

The fair was followed by the organization of an international fair for 2018, sensitizing the policy makers of other states, central government and also other nations, to rope into the millets movement.

Unless millet consumption increases, farmers will not get any sizeable benefits from the cultivation. The objective of millet promotion is aimed at creating more demand for millets to provide better incomes for millet farmers. "We are striving to connect millet farmers directly with retail companies so as to increase price realisation for farmers," says Mr. Krishna Byre Gowda, Minister of Agriculture, Karnataka. The visionary leader Mr. Gowda also pitched in at the Food

and Agriculture Organization (FAO) meeting in Rome in 2017 to plead for United Nations to declare a year as 'International Year of Millets (IYM)'.

Implementation of IYM would involving planning and sponsoring by FAO, national governments and other international organizations for the world-wide promotion of millets - awareness, production and consumption - for the benefit of mankind.

Hon'ble Agriculture Minister of Karnataka, Mr. Krishna Byre Gowda, Ambassador for Millets

Millets were the first crops; Millets are the future crops

Millets are our own super foods as more and more research findings are revealing now. The beneficial effects of millets are also understood by the fewer diseases and longer lives that our millet-consuming elders had just a couple of generations ago. Higher calcium and potassium content in finger millet, higher iron and beta carotene in pearl millet, greater energy content in pearl millet and little millet are some of the goodness in the millets besides their ability to provide wholesome nutrition as staple foods. Millets, including amaranth are the super foods of our own country. A diet consisting of finger millet and pearl millet would provide richer nutrition than quinoa. Due to lack of awareness and availability these millets have not found their place in the modern food basket. Now we are seeing increase in awareness and demand for millets in urban and semi-urban societies. Also, beside the conventional staple foods, "ready to cook" and "ready to eat" processed foods made from millets are entering the market in a big way.

Why millets are the future crops

Millets are diverse and adapted to different climatic conditions and cropping systems, provide a strong case to enrich biodiversity as well as diversify the food grain basket. Under the climate change scenario, millets are the most dependable food crops the mankind, especially for the resource poor dryland farmers of the world as they are resilient to climate change and assure sustainable grain production with minimum inputs. Supporting millets is akin to supporting dryland agricultural ecology (40% of land area that supports 30% of world population) where food insecurity and malnutrition are commonplace. Eradication of hunger is a major priority in these regions as under nutrition accounts for 11 per cent of the global burden of disease and is considered the number one risk to health worldwide.

Rich diversity of millets crops has made them well suited for contingency crop planning and also to address the issues of climate change. The plasticity exhibited has made them flexible for apparent early as well as delayed planting, very low and high rainfall areas, various elevations and different soil regimes. These positive features have not been duly recognized and exploited in the country. The versatile small millets like foxtail millet, barnyard millet, proso millet and little millet would fit in any situations of climatic change and would save the farmers from a total crop failure. The farmers who had shifted from millets to other crops are keen to go back to millets in view of the stable harvests ensured, easy crop production, drought resistance, and eco-friendly production, provided the assured market is in place.

Enhanced millets production and consumption directly facilitates improving malnourishment and correcting the slow growth in correction of nutritional disorders such as anemia, surging lifestyle disorders such as diabetes, hypertension, metabolic syndrome, gluten intolerance *etc.* Data on scientific evidences for nutritional and health benefit claims of millets are now available for projecting them as superior nutritious cereals beneficial for human health. In addition, millet foods are being made available in ready-to-eat and ready-to-cook forms.

World's most disadvantaged regions get fodder from millet crops as an important byproduct that is richer in nutrition for cattle, still face a huge deficit of roughages for livestock. Millets such as sorghum and pearl millet and their hybrids produce more quantities of green forage per unit area and unit time. They are also the potential feedstalks for biofuel, a source of renewable and environment friendly raw material for cleaner fuel, circumventing the food versus fuel debate.

This new demand for millets, leading to higher prices, can make their cultivation profitable, ensuring the legitimate place for millets in the national food basket. However, it is important to ensure that the demand just does not end up becoming a fad that might evaporate in a few years. Consumers also have more options now. Exotic and novel super foods such as quinoa, chia, *etc.*, also form options for the urban consumer. All the concerned stakeholders involved in research and popularization are working to explore the realistic benefits of millets consumption in their earnest to ensure this and more importantly, not to get lost in the overzealous trade and far-f*etc.*ed propaganda. Millets which played a crucial role for humans to adopt sedentary life from hunter-gatherer ways, can also support healthy living in a good environment. It is for us to take a plunge and say 'Lets millet'!

Source: *Sahaja Samrudha*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