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REVIEW ARTICLE

ORIGIN, DOMESTICATION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY AND BREEDING OF LITTLE MILLET (*Panicum sumatrense* Roth. Ex. Roem. & Schult.)

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ABSTRACT

Little millet belongs to the family Poaceae, sub-family Panicoideae, tribe Paniceae, Genus *Panicum* Species *Panicum sumatrense*. Little millet (*Panicum sumatrense* Roth. Ex. Roemer and Schultes) is grown in India under various agro ecological situations. The time to maturity for most cultivars is about 90 days. Little millet is grown throughout India up to altitudes of 2100 m, but it has only a little importance in different places. Little millet is a tetraploid with $2n = 4x = 36$. 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. Any recipe made with staple rice can be prepared using little millets with similar taste. Perhaps very little of this species is grown outside of India. Little millet is commonly available across the country as a whole grain. Millet flour can be procured from certain sources or more commonly could be made at home. Practically devoid of grain storage pests, the little millets have indefinite storage life. Little millet has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with other nutrients. Little millet is cooked like rice. Sometimes the millet is also milled and baked. The protein content of the grain is 7.7%. The English names for little millet are Indian millet, Tribal millet and small millet. Little millet is reported to be predominantly grown in the eastern parts of India, where it forms part of tribal agriculture. Little millet is known for the highest content of crude fibre in its grains. Little millet is one of the small millets commonly known as 'kutki' in Hindi, 'samai' in Tamil, 'same' in Kannada and 'samalu' in Telugu. As these millets are smaller in size, they cook faster than rice and other millets. Little millets could be milled into flour for making roti, baked and fried items.The whole grains can be sprouted and used in salads. Dosa, upma, kichidi, tomato rice, lemon rice, curd rice, porridge, chakli, payasam, halwa and kesari are few traditional recipes prepared in different millet growing states in India. Little millet is native to India and is also called Indian millet. It is mainly grown in the Caucasus, China, East Asia, India, and Malaysia. Little millets are nutritious, healthy and versatile with similar comparison to other cereals and can be a worthy addition to diet. Little millet based value added products could enhance the income, empowers millet farmers and nutrition in rural India. The dehusked grain of little 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. In India, little millet growing states are Karnataka, Tamil Nadu, Odisha, Madhya Pradesh, Chhattisgarh, Jharkhand, Andhra Pradesh, Uttarakhand, Maharashtra and Gujarat. In Gujarat, generally little millet crop is grown in hilly tract of The Dangs and Valsad district and locally known as "Vari or Moraio". Little millet is a hardy crop which can withstand drought better than most of other cereal crops and water logging to a certain degree, also. The potentiality of little millet has not been exploited in India and the yield levels are very low there by indicating a greater scope for exploitation of this millet under Indian condition. Mutation breeding was used as one of the strategy in addition to conventional breeding methods for genetic improvement of little millet. Mutation breeding was used as complement approach to conventional breeding methods for genetic improvement of little millet. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Little Millet are discussed.

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INTRODUCTION

Little millet is a self pollinating crop. Small, yellow and gluten free. Little millet is another reliable catch crop as it is resistant against extreme agro-climatic conditions. It has received comparatively little attention from plant breeders. The plant varies in height between 30 and 90 cm. It is mostly grown along with other millets, pulses and oilseeds. The seeds of little millet are smaller than those of common millet. Eating little millet in summer is the best way to beat the heat. Hence, it is called "cool food." The millet grains are rich in dietary fibre, protein and minerals and guards us against diabetes, blood pressure, constipation and obesity. Its easy digestible property makes it an ideal crunchy breakfast snack for all age groups (The Hindu, 2015). Little millet is widely grown in marginal areas andpredominantly as rainfed crop with poor managementby resource poor farmers. The crop is strongly associated with tribal agriculture. Sparse and irregular cultivation of little millet has led to less understanding of genetic diversity. In India, fragile hilly ecosystem under droughtand unsure rainfall areas, farmers prefer to grow relatively drought tolerant millets, particularly little millet. Little millet is the staple food for millions in many parts of the world especially among tribal. It is particularly grown in the Eastern Ghats of India,where it forms an important part of tribal agriculture. It is a quick growing food grain cereal and has low water requirement. Its wider adaptability, higher grain nutritional quality and longer shelf life under ambient conditions makes it a preferred crop of tribal farmers (Selvi *et al*., 2015). It is recognized for its resistance to drought, owing to which it is one of the least water-demanding crops and can be grown in both subtropical and tropical climates (Nagaraja *et al*., 2023). Little millet belongs to the family Poaceae, sub-family Panicoideae, tribe Paniceae, Genus *Panicum* Species *Panicum sumatrense* (Saloni *et al*., 2018; Ladumore *et al.,* 2021). Little millet (*Panicum sumatrense* Roth. Ex. Roemer and Schultes) is grown in India under various agro ecological situations. The time to maturity for most cultivars is about 90 days (Goron and Raizada, 2015). Little millet is grown throughout India up to altitudes of 2100 m, but it has only a little importance in different places (Indirani and Devasena, 2021). Little millet is a tetraploid with $2n = 4x = 36$ (Goron and Raizada, 2015). Little millet matures quickly and withstands both drought andwater logging. Less genetic diversity occurs in the world collections of this speciesthan 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 (Bhat *et al.,* 2018). Little millet is commonly available across the country as a whole grain. Millet flour can be procured from certain sources or more commonly could be made at home. Practically devoid of grain storage pests, the little millets have indefinite storage life (Jhawer, 2017). Little millet has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with other nutrients (Jhawer, 2017). Little millet is cooked like rice. Sometimes the millet is also milled and baked. The protein content of the grain is 7.7%. (Wikipedia, 2023)

The English names for little millet are Indian millet, Tribal millet and small millet. Little millet, also known as Small millet, is a species of millet commonly cultivated in southern parts of India. Common names of little millet in different languages are: in Bengali : Sama, Gujarati : Gajro, Hindi: Kuri,: Kannada: same, Marathi: Save, Oriya: Suan, Punjabi: swank, Tamil: Samai and Telugu: Samalu (The Hindu, 2015). The common names in Indian languages are given in **Table 1** (Distacart, 2020; Ladumore *et al.,* 2021; Wikipedia, 2023; Prakash, 2023; Hariprasanna, 2023; Indianmed, 2023).

Table 1. Common names of little millet in Indian languages

Language	Little millet
Kannada	Same
Tamil	Samai
Telugu	Samalu
Malayalam	Sama
Marathi	Sava
Gujarati	Gajro, Kuri
Bengali	Sama
Oriya	Suan
Punjabi	Swank
Kashmiri	Ganuhaar

The millets comprise at least 11 cultivated species, all with small to tiny seeds. Sorghum and millets are notably hardy crop plants, having a low water requirement. They are predominantly cultivated in tropical and subtropical zones in Africa and Eurasia, where they were domesticated several thousand years ago. The traditional food and beverage uses of sorghum and millets are extremely wide. Also, they have many novel applications such as for lager beer, gluten-free products and phytochemicals, and sweet-stalked and biomass sorghums for biofuels. However, production trends reveal a disturbing picture that overall sorghum and millet production and yields have remained static over the past 25 years. Furthermore, in low-income countries, yields remain chronically low (Taylor, 2019). Minor millets are an agronomic community of genetically diverse species of cereal grasses, well adapted to a range of marginal growing conditions where major cereals are relatively ineffective, such as wheat, rice, and maize. Minor millets are grown in various soils in India, in varying rainfall regimes, and in areas where thermal and photographic cycles vary widely. Seven cultivated species, *viz*., finger millet, barnyard millet, foxtail millet, proso millet, little millet, kodo millet, and browntop millet represent minor millets. These millets provide millions of households with highly nutritious food and livelihood security, especially small and marginal farmers and residents of rainfed areas, particularly in remote tribal areas. They are now no longer referred to as coarse cereals but as nutricereals or nutraceutical crops, and are considered as a plausible answer to combat malnutrition and secret hunger worldwide. Indian tribal groups have a special link to minor millets as these crops have been an integral component of their agricultural systems and operations. Minor millets are being used by them from time immemorial not only to fight hunger but also for ethnomedical uses (Rawat *et al*., 2021). Generally, millets are considered to be a group of variable small-seeded grasses. Those grasses have widely grown the world as cereal crops or grains which is used as a source of food. They are a very important category of the food system and crops in the Asian strata like India and a report of 97% of crops are grown out in such developing nations. The temperature in such areas is a questionable statement for its massive production. It is indigenous to variant parts of the world and has become an inevitable part of the human food system (Vincent, 2023). Little millet is reported to be predominantly grown in the eastern parts of India, where it forms part of tribal agriculture. Little millet is known for the highest content of crude fibre in its grains (Ganapathy, 2017). Little millet is one of the small millets commonly known as 'kutki' in Hindi, 'samai' in Tamil and 'samalu' in Telugu. It is grown throughout India as a traditional crop and although related to proso millets has seeds much smaller than them. It is mostly consumed as rice. Any recipe made with staple rice can be prepared using little millets with similar taste. As these millets are smaller in size, they cook faster than rice and other millets. Little millets could be milled into flour for making roti, baked and fried items.The whole grains can be sprouted and used in salads.

Dosa, upma, kichidi, tomato rice, lemon rice, curd rice, porridge, chakli, payasam, halwa and kesari are few traditional recipes prepared in different millet growing states in India (Neeharika *et al*., 2020). Indian little millet has a short crop cycle and mostly cultivated under natural rainfed irrigation but can grow even during relatively dry seasons under artificial irrigation. It is suitable for both dry and waterlogged conditions with adverse environments such as salty soils and high temperatures. As little millet gives consistent yield on marginal lands in drought prone arid and semiarid regions, it can be an important crop for regional food stability and nutritional security. The grains are practically devoid of storage pests with indefinite storage life (Neeharika *et al*., 2020). Little millets are nutritious, healthy and versatile with similar comparison to other cereals and can be a worthy addition to diet. Little millet based value added products could enhance the income, empowers millet farmers and nutrition in rural India. Malnutrition is a serious matter of concern among world population due to modern lifestyle specifically consumption of rapidly processed fast food and evolving dietary habits. The present situation where hidden hunger is on the rise demands development of food products that are rich in nutrients, readily acceptable, meet requirement of growth and development cost effectively. The utilization of little millets for development of various value added, therapeutic and functional products apart from traditional food preparations can increase the demand for this grain in terms of production as it is currently declining due to less utilisation (Neeharika *et al*., 2020). Little millet is a small-grained cereal belonging to the millet family. Its history dates back to thousands of years in India. It is grown mostly in Southern India. This hardy crop thrives in diverse agro-climatic conditions, making it a sustainable option for farmers. Little millet is resistant to pests and illnesses, making it a good choice for organic farming. With its nutty flavor and versatile culinary uses, little millet has gained popularity as a nutritious and environmentally-friendly grain option. Little millet benefits are far ahead of what we think (Nutritionfact ,2023). The crop is highly drought tolerant andnutritionally as well as medicinally superior or at par withother cultivated cereals. Grains are recommended for diabetic and patients of cardio –vascular diseases. The grain of little millet posses excellent storage propertiesand can be stored for several years without fear of storegrain pests under ordinary storage conditions. Little milletis well known for its drought toleranceand is consideredas one of the least water demanding crop. Being eco- friendly, the crop is suitable for fragile and vulnerable agro-ecosystems (Saloni *et al*., 2018). The crop is cultivated by tribal and poor farmers in low fertile soils with low or no cash input for food andfeed. It has an excellent rejuvenating capacity comparedto other cereal crops. In India, the crop is cultivated in an area of 291 thousand hectares with annual production of 102 thousand tones and productivity of 349 kg per hectare which is very less as compared to other cereal crops. It originated in the Indiansubcontinent (Saloni *et al*., 2018). Little millet is native to India and is also called Indian millet. It is mainly grown in the Caucasus, China, East Asia, India, and Malaysia. Little millet is altered to both temperate and tropical climates and it also can withstand drought and water logging. At present, the crop is almost limited to around hilly areas in India and it isgrown on about 500,000 ha. It is a significant faster growing crop in some tribal farms in India (Indirani and Devasena, 2021). Little millet is cultivated to a limited extent in India, Sri Lanka, Pakistan, Myanmar, and other South East Asian countries. In India it is important to tribes of the Eastern Ghat mountains and grown in combination with other millets. Little millet isa domesticated form of the weedy species *Panicum psilopodium* (Goron and Raizada, 2015). The plant originated in the Andes and is a hybrid ofwild *Panicum sumatrense* L. subspecies *quitensis* (Kunth) Costea and Carretero and the cultivated *Panicum sumatrense* (Saloni et al., 2018). These are distributed across the temperate zones of Asia: the Caucasus, China, East Asia, and also in the tropics of the continent: India, Indochina, and Malaysia (Indianmed, 2023). At the Indus Valley civilisation sites of Harappa and Farmana, the millet assemblage was dominated by little millet. Over 10,000 grains of little millet were recovered at Harappa. At Harappa, little millet cultivation peaked at around 2600 BC, accounting for around 5% of the total cereal assemblage (Wikipedia, 2023). Mutation breeding was used as one of the strategy in addition to conventional breeding methods for genetic improvement of little millet. Mutation breeding was used as complement approach to conventional breeding methods for genetic improvement of little millet (Ganapathy, 2017). There are two types of millets in India *viz.,* Naked grains and Husked grains (Vincent, 2023): Naked grains**:** Naked grains are three common types that are without the hard, indigestible husk that some millets possess. Specifically, such millet categories include, Ragi, Jowar, and Bajra. These millets don't demand processing after harvest. They can directly be utilized after being washed. These are the significant types that are extensively cultivated and entirely popular due to the availability and easy procedure as compared to the other millet and their long processes Husked grains**:** The second kind of millets is the Kodo millet, Foxtail millets and Little millets. These varieties have an indigestible seed coat. The husk on them needs to be separated prior they are fit for consumption. Millets include a multitude of micronutrients such as iron. Also, they take time to digest, which doesn't cause the blood sugar spike associated with easily digestible food. Adding millets into your diet can help you control diabetes.

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 ofrice. Often, rotiand 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 (Bhat *et al.,* 2018). Seeds of these millets are very small but easy to harvest and very nutritious. They are eaten cooked or ground into a powder and used for making cakes etc. They can also besprouted and used in salads. The seed can be cooked whole, and becomes very gelatinous, but it is rather difficult to crush all of the small seeds in the mouth and thus, some of the seed will pass right through the digestive system without being assimilated. The flowers are used as a food coloring in ceremonial maize bread (Saloni *et al*., 2018). Little Millet or samai plays a major role in the Indian diet. It is an excellent source of nutraceuticals and micro-nutrients which gives medicinal beneficial properties. Little millet is a minor cereal, and it is recognized for several health benefits due to the presence of bio-active nutraceuticals such as phenolic compounds, tocopherols, carotenoids, and low in glycaemic index mainly which is good for diabetic patients. It is a good source of phosphorus and the presence of fibre helps to lower the fat level in the body. The anti-oxidant and low-calorie content which is present in the samai, helps to maintain a balanced diet and weight that can promote weight loss (Indirani and Devasena, 2021).

Little millet is comparable to other cereals in terms of fiber, fat, carbohydrates, and protein, and rich in phytochemicals including phenolic acids, flavonoids, tannins, and phytate. Like many other small millets, it is drought, pest and salt tolerant (Goron and Raizada, 2015). It is one of Little millet is comparable with other cereal grains such as rice and wheat as a source of protein, fat, carbohydrates and crude fibre, apart from minerals and vitamins. It also contains phytochemicals such as phenolic acids, flavonoids, tannins and phytate (Saloni *et al*., 2018). Millets are the important sources of staple diet in the semi-arid tropics especially in Asia and Africa. Millets were almost forgotten crops until last decade. Recently there is a big comeback for millets considering its nutritional superiority and in-built climate resilience (Ganapathy *et al*., 2021). Due to highest in nutritive value of this crop, it is included under the "Nutricereal" crops (Ladumore *et al.,* 2021). Among cereals, little millet or samai has been found to have the highest amount of fiber. Its crude fiber content is nearly twice that of other cereals. Samai is rich in phenolic compounds that show antioxidant activity. This millet is an excellent source of Iron. One serving (30 g) can provide 16% of the daily iron needs for an adult man. Like other millets, Samai is also gluten-free. It makes up for the lack of wholegrain fiber in Celiac (gluten-free) diets. Samai has a low to medium glycaemic index thus is diabetic friendly. It is a rich source of the essential amino acids Histidine, Methionine, and Phenylalanine (Indianmed, 2023). *Samai dosa*, porridge, *paddu* and *payasam* from little millet are few traditional recipes in different millet growing states in India (Jhawer, 2017).

Also called *sama*, little millet is cultivated to a limited extent in India, Sri Lanka, Pakistan, Myanmar, and other South East Asian countries. In India it is important to tribes of the Eastern Ghat mountains and grown in combination with other millets. Little millet is a domesticated form of the weedy species *Panicum psilopodium* (Goron and Raizada, 2015). Andhra Pradesh, Chhattiishgarh, Madhya Pradesh, Odisa, Tamil Nadu, Karnataka, Jharkhand and Gujarat are major little millet growing states in the country (Saloni *et al*., 2018). Odisha, Madhya Pradesh, Chhattisgarh, Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Jharkhand are major little milletgrowing states in the country (Hariprasanna, 2023). In India, little millet growing states are Karnataka, Tamil Nadu, Odisha, Madhya Pradesh, Chhattisgarh, Jharkhand, Andhra Pradesh, Uttarakhand, Maharashtra and Gujarat. In Gujarat, generally little millet crop is grown in hilly tract of The Dangs and Valsad district and locally known as " Vari or Moraio" (Ladumore *et al.,* 2021). 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. India is well known for its rich agro-biodiversity and prime contributor with 473 accessions. In India, little millet having 1.42 lakh tones of production. In Gujarat, little millet is cultivated in an area of 10,634 hectares with 9,526 tonnes of production having the productivity of 896 kg/ha (Ladumore *et al*., 2021). Little millet is a hardy crop which can withstand drought better than most of other cereal crops and water logging to a certain degree, also. The potentiality of little millet has not been exploited in India and the yield levels are very low there by indicating a greater scope for exploitation of this millet under Indian condition (Ladumore *et al.,* 2021). It is grown across India, China, Nepal, Sri Lanka, and Western Burma. In India, it is cultivated in Karnataka, Tamil Nadu, Bihar, Andhra Pradesh, Maharashtra, Madhya Pradesh, Orissa, Uttar Pradesh, and Gujarat states (Nagaraja *et al*., 2023). Grain consists of husk 19%, bran 5% and edible matter 64% (Divya *et al.,* 2021).

Little millet is native to India and is also called Indian millet. This millet species name is originated from Sumatra (Indonesia). It is mainly grown in the Caucasus, China, East Asia, India, and Malaysia. Little millet is altered to both temperate and tropical climates and it also can withstand drought and water logging. At present, the crop is almost limited to around hilly areas in India and it is grown on about 500,000 ha. It is a significant faster growing crop in some tribal farms in India (The Hindu, 2015). The crop is grown in India in 6.67 lakh hectares as dry land crop in both black and red soils in kharif season with the production of 0.79 lakh tones. It is mainly grown in Tamil Nadu, Karnataka, Andhra Pradesh and Uttar Pradesh. Out of the total area of 1.2 lakh hectares in Tamil Nadu, 58,450 ha is grown in Dharmapuri and Krishnagiri districts representing 48% of the total area of the state under the crop. These two districts accounts for 76% (0.49 lakh tones) of the total production of the state with an average productivity of 836 kg/ha (Divya et al., 2021). In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Little Millet are discussed.

ORIGIN AND DOMESTICATION

According to references available with Pristine and Sahaja organics, an NGO which have brought out a book titled "Millet in your meals," sponsored by National Bank for agriculture and rural development there are about 6,000 varieties of millets throughout the world with grains varying in colours from pale yellow, gray, white, and red. Archaeologists say that foxtail millet is so old that no wild plant of the species is known to exist today. It also says that the grain has been a part of the human food system from time immemorial. According to the book, many types of millet have been found in Harappan and Mohenjodaro archaeological sites. Africa, the cradle of human civilization, the Mayans, Incas and Aztecs were known to use millets in their culinary courses. Hindu vedic scriptures make references to the millets in Sathapatha Brahmana. In 'Shakuntala,' Kalidasa has spoken about a sage Kanva who pours foxtail millet while bidding farewell to Shakuntala in Dushanta's court. The oldest historical roots of millet are to be found in China, where it was considered a sacred crop. The leader of the Shang Dynasty in the 2nd millennium BC was known as Hou Chi 'The ruler of Millet.' The book says that people of Northern India were also cultivating millet, during the prehistoric times. Millet has travelled throughout the Middle East and Northern Africa where it became a staple. It further became typical food of the Sumerian diet about 2500 BC. Even the Hebrew bible makes mentions about the humble millet. The Hanging Gardens of Babylon were said to have included millet among their treasured plants. Through trading with Eritrea and Somalia circa 3000 BC, the early Egyptians learned from the Africans how to cultivate millet, which would grow well in the dry Sahara, where wheat and barley were unable to thrive. The interesting fact is that this is also pointed out in the Bible, and was used during those days to prepare bread (The Hindu, 2015). Also called *sama*, little millet is cultivated to a limited extent in India, Sri Lanka, Pakistan, Myanmar, and other South East Asiancountries. In India it is important to tribes of the Eastern Ghat mountains and grown in combination with other millets. Little millet is a domesticated form of the weedy species *Panicum psilopodium*. Little millet is distributed in India, Sri Lanka, Pakistan, Myanmar, and other South East Asian (Goron and Raizada, 2015)

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 and useful fodder under very poor conditions. Some forms mature in as little as two-and-a-half months. 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. 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. 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 (Bhat *et al*., 2018). The plant originated in the Andes and is a hybrid of wild *Panicum sumatrense* L. subspecies *quitensis* (Kunth) Costea and Carretero and the cultivated *Panicum sumatrense* (Saloni *et al*., 2018).

The origin of little millet is not well documented and considered as Indian origin (Maitra and Shankar, 2019). This millet was cultivated or naturalized in India and Sri Lanka, and cultivated in neighbouring countries and no diversity and related wild species are found outside India, suggestive of Indian origin. In the archaeological excavations of Gujarat dating to 2000-1500 BC presence of little millet seeds was evidenced. The cultivation of little millet is mainly observed in the states of Karnataka, Madhya Pradesh, Andhra Pradesh, Odisha, Tamil Nadu, Gujarat, Chattisgarh and Maharashtra (Maitra and Shankar, 2019). Little millet, *P. sumatrense*, is native to India and is also called Indian millet. This millet species nameis originated from Sumatra (Indonesia). It is mainly grown in the Caucasus, China, East Asia, India, and Malaysia. Little millet is altered to both temperate and tropical climates and it also can withstand drought and water logging. At present, the crop is almost limited to around hilly areas in India and it isgrown on about 500,000 ha. It is a significant faster growing crop in some tribal farms in India (Indirani and Devasena, 2021). The origin of little millet is not well recognized and considered as Indian origin. The crop has a name in all vernacular languages of India. This milletwas cultivated throughout India and Sri Lanka, and cultivated in neighbouring countries and wild

species are not found outside India, suggestive of Indian origin. Archaeological evidences suggest that the seeds of little millet were evidenced at Gujarat - 2000- 1500 BC (Divya *et al*., 2021).

The area under other small millets has reduced by more than half with proportionate reduction in total production. The productivity remained low and stagnant around 450 kg/ha. Though more recent and accurate statistics regarding each of the small millets is lacking a broad picture is that more than 60% of area under small millets is occupied by finger millet, distantly followed by little and kodo millets (just above 10%) and rest by barnyard, foxtail and proso millets. Though small millets are grown in almost every state/region, the distribution of individual millet is not uniform. The kodo, little and foxtail millets are grown widely in Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Madhya Pradesh and Maharashtra **(**Vikaspedia, 2022**).** In the temperate zones of Asia: the Caucasus, China, East Asia and also in the tropics of the continent: India, Indochina and Malaysia. It can withstand both drought and water logging. It can be cultivated up to 2000 m above sea level (Wikipedia, 2023). At the Indus Valley civilisation sites of Harappa and Farmana, the millet assemblage was dominated by little millet.[6] Over 10,000 grains of little millet were recovered at Harappa. At Harappa, little millet cultivation peaked at around 2600 BC, accounting for around 5% of the total cereal assemblage (Wikipedia, 2023).

TAXONOMY

Small millets belong to nine different genera of the grass family *Poaceae*. **Fig. 1** shows the taxonomical classification of small millets, together with major cereals, and pseudo-cereals (Vetriventhan *et al*., 2020).

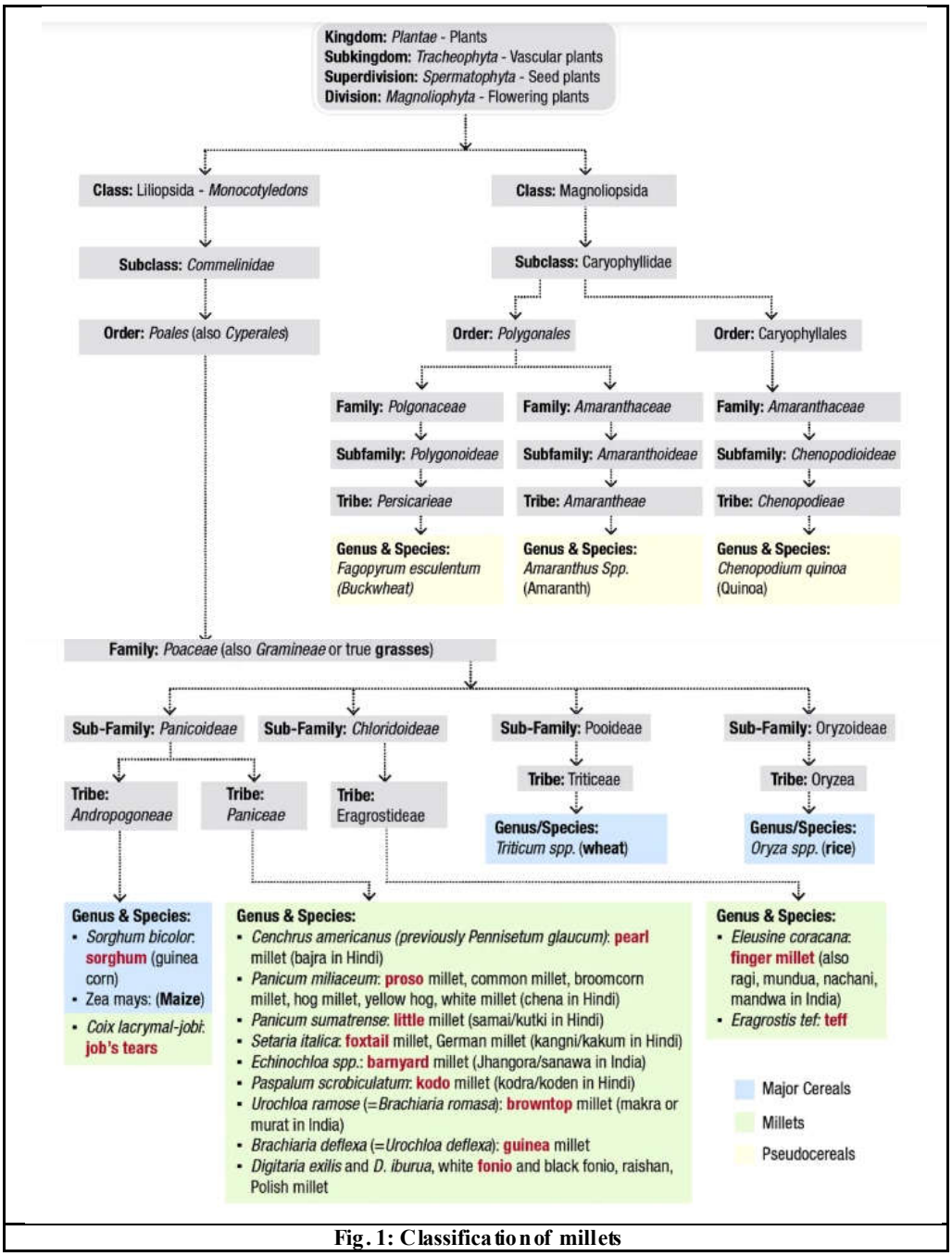


Fig. 1: Classification of millets

"Millet" is not a botanic term for a certain plant but rather an umbrella term for various small seeded grasses used for human consumption. All millets belong to the order of *Poales*, and there to the family of *Poaceae* (also *Gramineae* or true grasses). They belong to either of the two subfamilies of *Panicoideae* or *Chloridoideae* (TMP, 2023):

Eragrostideae tribe (*Chloridoideae* subfamily)

- **Eleusine coracana**: finger millet, mawere (ragi, nachani or mandwa in India)
- **Eragrostis tef**: teff

Paniceae tribe (***Panicoideae*** subfamily):

- **Panicum miliaceum:** proso millet, common millet, broomcorn millet, hog millet, yellow hog, white millet
- **Pennisetum glaucum**: pearl millet (kambu or bajra in India)
- **Setaria italica:** foxtail millet, German millet (thinai, kang or rala in India)
- **Digitaria** spp.: white fonio, black fonio, raishan, Polish millet
- **Echinochloa** spp.: Japanese barnyard millet, Indian barnyard millet, sawa millet, burgu millet (kuthirai vaali, bhagar or varai in India)
- **Panicum sumatrense**: little millet (samai in India)
- **Paspalum scrobiculatum**: kodo millet (varagu in India)
- **Urochloa** spp. (also known as **Brachiaria**): browntop millet (*U. ramosa*, dixie signalgrass), Guinea millet

Andropogoneae tribe (***Panicoideae*** subfamily):

- Coix: Job's tears.

Little millet belongs to the family Poaceae, sub-family Panicoideae, tribe Paniceae, Genus *Panicum* pecies *Panicum sumatrense* (Saloni *et al*., 2018; Ladumore *et al*., 2021). The Scintific name of little millet is *Panicum sumatrense* Roth. ex Roem. & Schult. And the synonym is *P. miliare* auct. pl. (Bhat *et al*., 2018). Little millet is grown in India under various agro ecological situations. The time to maturity for most cultivars is about 90 days (Goron and Raizada, 2015). Little millet is grown throughout India up to altitudes of 2100 m, but it has only a little importance in different places (Indirani and Devasena, 2021). Little millet is a tetraploid with $2n = 4x = 36$ (Goron and Raizada, 2015). Little millet matures quickly and withstands both drought andwater logging. Less genetic diversity occurs in the world collections ofthis 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 (Bhat *et al*., 2018). Little millet is commonly available across the country as a whole grain. Millet flour can be procured from certain sources or more commonly could be made at home. Practically devoid of grain storage pests, the little millets have indefinite storage life (Jhawer, 2017). Little millet has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with other nutrients (Jhawer, 2017). Little millet is cooked like rice. Sometimes the millet is also milled and baked. The protein content of the grain is 7.7%. (Wikipedia, 2023)

Races: Little millet is divided into two races based on panicle morphology, *nana* and *robusta*. Race *nana* matures faster and produces less biomass than *robusta* (Goron and Raizada, 2015; Ganapathy, 2017; Indirani and Devasena, 2021). Little millet (*Panicum sumatrense*), was first grown in Indian peninsula. There are two types of little millet namely, *nana* and *robusta.* The type of *nana* varies plants that can grow about 60 to 170 cm in height and the inflorescence is 14–15 cm long, erect, open, and highly branched. These branches sometimes droop at maturity. Plants in the race of *robusta* are 120–190 cm tall and the inflorescence is 20–45 cm long, opening compact, and highly branched (Indirani and Devasena, 2021). Plants in the race of *robusta* are 120–190 cm tall and the inflorescence is 20–45 cm long, opening compact, and highly branched. It is primarily a self-pollinated crop with approximately 3 5% cross-pollination (Indirani and Devasena, 2021).

There have been two subspecies described *viz.*,

- *Panicum sumatrense* Roth ex Roem. & Schult. subsp. *psilopodium* (Trin.) Wet.
- *Panicum sumatrense* Roth ex Roem. & Schult. subsp. *Sumatrense*

Taxonomy/Types of samai rice (Indirani and Devasena, 2021).

Sadan samai: Sadan samai is an annual top knotted grass species with slender culms, 90-120 cm high at harvest depending upon the soil fertility, narrow leaves with soft margin, 45-60 cm long and 8-10 cm broad, panicle loose drooping with primary and secondary branches, spikelet 4-4.5 mm, long, globous, flattened, caryopsis glorious light. It is an early maturing race (100-120 days) cultivated as a mono-crop in a terraced field. It is less profuse in tillering; pink colour pigmentation is present at the base of the second or third intermodal area. Sadan samai is cultivated at high altitude which ranging from 1200-1400mt that means above sea level. It needs a cool climate as compared to other landraces. Since the tertiary brushwood of the ear head look like the plait of a bride, this millet is commonly known as Sadan (Sadai = plait of a bride) samai. This samai variety is grown in dense which is very difficult to harvest.

Kattavetti Samai: It is annual erect grass species with thicker culms, narrow leaves with a serrated margin of 75-90 cm long, 150-180 cm in height at the harvest depending upon the soil fertility and 8-10 cm broad, panicle loose drooping primary and secondary branches spikelet 5-5.5 mm, long, glabrous, flattened, caryopsis glabrous light brown color in grains. Kattavetti samai is a late-maturing variety, usually cultivated in rocky terrain or kola kaduunder a bush fallow system. In case of extreme vegetative growth due to good soil fertility and favorable climatic conditions, farmers cut the crop above the unopened panicle during tillering phase mainly to induce the early maturity of the spikelet and to arrest the further vegetative growth that will empower the early harvest of the crop. The tillers of Kattavetti samai are very thick as that of the early tillers of sugarcane. The thick tillers arereferred to as Kattai (Wood in Tamil) and while harvesting they use a sickle of a bigger size locally called vetti (cut). The combination of these two terms makes this name different i.e., Kattavetti samai rice.

Thirukula samai: It is also erect grass species with thinner culms, 90-100 cm high at harvest depending upon the soil fertility, narrow leaves with soft margin 45-60 cm long and 6- 7 cm broad, panicle loose drooping primary and secondary branches, spikelet 5- 5.5 mm long, glabrous, flattened, caryopsis glabrous dark brown color in grains. It is tolerant to drought and high temperatures than other races.

Thirukula samai can be raised as monocrop or as a mixed crop with perum samai. The secondary branches in the panicles are arranged in a twisted manner like a thin rope- thiri indicates twisted and kula implies the short stature of the crop and thus it is called Thirukula samai.

Mallia samai: This type of samai also belongs to yearly erect grass species with very little tillers, 80-100 cm high at harvest, a very thin leaves with soft margin, 35-50 cm long and 3-6 cm broad, panicle loose drooping primary and secondary branches, spikelet 4- 4.5 mm long, glabrous, flattened, caryopsis glabrous dark brown color grains. It is mostly raised as an early crop using summer showers before the main agricultural sowing season (June – July) in the terraced fields. It is an early maturing low tillering race mostly cultivated as a monocrop in the terraced field and also as a mixed crop with Perum samai. The reason for cultivating this particular race is that it enables the farmers to harvest grains during off-season agriculture. According to the people, the grains of Mallia samai is white in color and soft in texture. Because of its color (like the jasmine flowers which are called Malli) and texture, the farmer calls it so.

Perum samai: This grass species with thicker culms 160-190 cm high at harvest depending upon the soil fertility, narrow leaves with serrated margin 75-90 cm high and 8-10 cm broad, panicle loose-fitting primary and secondary brushwood, spikelet 5- 5.5 mm long, glabrous, flattened, caryopsis glabrous dark brown color in grains. It is a late maturing race and cultivated in the high hillocks (Kolla kadu) and in some places in the terraced fields in the crop mixtures i.e., in finger millet-based mixed cropping systems. Perum refers to the tall height of the crop as well as the lengthy period of its cultivation. Due to its dense growth and the sharpness of the leaf blades is a major problem during harvesting periods. The sharpness causes small skin irritations to those, who are harvesting it. This is cited as one of the reasons for its less preference to cultivate it.

Vellaperum samai: In this species of Poaceae family with thicker culms 170-190 cm high, 85-90 cm height, and 8-10cm broad which is light brown colour in grains. Vellaperum samai resembles like the Perum samai in its growth. The only difference is in the colour of caryopsis, which is whitish brown (vellai in Tamil denotes colour of white) colour whereas the latter is dark brown. Some of the women and men farmers said these races are one and the same. According to them, the difference in the colour of caryopsis is only due to the type of the soil and agro-climatic conditions.

Kottapatti samai: It also belongs to grass species with thicker culms, 150-160 cm high at harvest depending upon the soil fertility, narrow leaves with a serrated margin, 75-80 cm height and 7-8 cm broad, panicle loose drooping primary and secondary branches, spikelet 5- 5.5 mm long, glabrous, flattened, caryopsis glabrous dark brown colour in grains. It is a late maturing variety and prone to lodging problems particularly during periods of heavy winds. Because of this character, its cultivation is almost reduced, and only in few remote places, it is still cultivated on a smaller scale where the problem of wind is less.

BOTANICAL DESCRIPTION

Little millet (*Panicum sumatrense* Roth. ex Roem. & Schult.) is also known as miliare. It is widely cultivated as a cereal across India, Nepal, and western Myanmar. It is particularly important in the eastern ghats of India, where it forms an important part of tribal agriculture. A comparative morphological study of accessions resulted in the recognition of two races. Race *nana* plants are small (60 cm) to large (170 cm) with decumbent culms that root at the lower nodes before becoming erect to produce flowering culms. Terminal inflorescences are 14–50 cm long, erect, open, and strongly branched, with the branches sometimes clumped at the time of maturity. Race *robusta* includes plants that are erect, or produce flowering culms from a shortly geniculate base. Flowering culms are 120–190 cm tall and robust. Terminal inflorescences are 20–46 cm long, open, or compact and strongly branched. Open inflorescences are essentially erect, and compact inflorescences become curved at maturity. It is largely a selfpollinated crop; natural cross-pollination can occur up to 3.5%. The dehusked grain is cooked and consumed like rice, or is milled into flour. The crop thrives under conditions that will sustain no other edible plant and will mature in 2–5 months (Gomez and Gupta**,** 2003).

The plant is 5 – 2.5 m tall mostly reddish or purplish in colour, stout stems, partially branched with long hairs. Leaves arranged spirally, simple and entire; stipules are absent; petiole is upto 8 cm long; blade broadly ovate rhomboid-ovate, Inflorescence large (upto 1.5 m) and complex, consisting of numerous agglomerated cymes a axillary and terminal spikes, the terminal one pendant to erect; bracts 3–4 mm long, membranous, pale, with a long awn. Flowers unisexual, sessile; with 5 mucronate tepals stamens c. 1 mm long; female flowers crowned by 3 stigmas. Fruit an ovoid long, circumscissile, almost smooth or slightly furrowed, abruptly narrowed to a short thick beak, 1-seeded (Saloni *et al.,* 2018). Little millets known as saamai or kutki are short-duration millets and withstand both drought and water logging. Little millet is also a yearly crop having 30–90-cm hollow jointed stem with slender and robust base. The leaves are linear and can be 15–50 cm in length to 12–25 cm in breadth, while the nodes are glabrous. The seeds are grown during the period from June to July or between February and March. Its grain size is approximately 2.5 x 1.5 mm with 1.9 g of approximate kernel weight oval in shape, and the colour is creamy with shiny appearance. "Cool food" is another name for little millet because of the cooling impact it has on the body when consumed in summer time (Dey *et al.,* 2022). Little millet is similar in habit to the proso millet except that it is smaller. It is an annual herbaceous plant, which grows straight or with folded blades to a height of 30 centimetres (12 in) to 1 metre (39 in). The leaves are linear, with the sometimes hairy laminae and membranous hairy ligules. The panicles are from 4 to 15 cm (1.6 to 5.9 in) in length with 2 to 3.5 mm (0.079 to 0.138 in) long awn. The grain is round and smooth, 1.8 to 1.9 mm (0.071 to 0.075 in) long. The seed size is 2-3 mm in length. Grain shape is elliptical to oval shape and its colour vary from grey to straw white (Fig. 2, 3) (Wikipedia, 2023).

Seedling

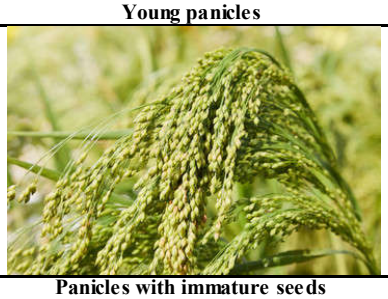
Seedling

Panicles

Young panicles

Panicles with immature seeds

Field



Panicles with immature seeds

Panicles with mature seeds

Panicles with mature seeds

Field ready for harvest

Seeds

Grains

Fig. 2. Botanical Description

Fig. 3. Close-up photo of Little Millet grains

It is primarily a self-pollinated crop with approximately 3.5% cross-pollination. Little millet is grown throughout India up to altitudes of 2100 m, but it has only a little importance in different places (Indirani and Devasena, 2021).

Floral biology and anthesis: The inflorescence of little millet is a panicle that is 15 to 45 cm long, 1 to 5 cm broad, and constricted or thyrsiform. The persistent spikelet is 2 to 3.5 mm in length. When panicles reach maturity, they become scabrous and droop. Each spikelet flowers for around 2 to 5 min. The top one is fertile or bisexual without rachilla expansion, whereas the lower one is sterile. The fertile flower is enclosed by lemma II and its palea, while the staminated or sterile flower is enclosed by lemma I and its palea. Spikelets are elliptical, dorsally compressed, and acute, with three anthers of about 1.5 mm in length. The glume that reaches the apex of florets is thinner than the fertile lemma. The lower glume is ovate, membranous, with no keels, possesses one to three veins, and is about 0.7 to 1.2 mm long. The apex of the lower glume is acute. An ovate upper glume is larger than the lower glume, and the keel is absent. It has 11 to 15 veins **(Fig. 4)** (Nagaraja *et al*., 2023). The spikelet opening begins on the second or third day after the appearance of the panicle. The process of flowering is basipetal. Maximum flower opening is seen on the sixth or seventh day of flowering. For complete flowering in a panicle, about 2 weeks are required.

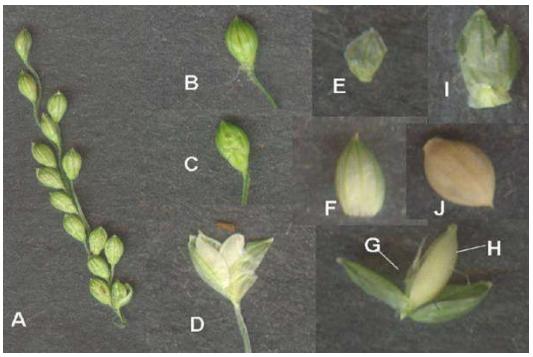


Fig. 4. Little millet inflorescence and its parts. (A) Inflorescence. (B) Spikelet. (C) Abaxial view of spikelet. (D) Opened spikelet. (E) Outer glume. (F) First lemma. (G) Sterile floret. (H) Fertile floret. (I) Upper glume. (J) Grain enclosed in lemma and palea

The panicle blossoms around 9:30 to 10:30 a.m. Since the glumes are opened for a limited duration, self-pollination is the rule. It takes 2 to 5 min to complete the process of anthesis **(Fig.5**) (Nagaraja *et al*., 2023).

Fig. 5. Blooming in little millet

Little millet inflorescence is a panicle, contracted or thyrsiform and 15-45 cm long and 1-5 cm in wide. The spikelet is persistent and 2-3.5 mm long. Panicle branches are scabrous and drooping at the time of maturity. Spikelets produce on unequal pedicels but solitary at the end of the branches. Each spikelet consists of two minute flowers. The lower one is sterile; the upper one is fertile or bisexual without rachilla extension. The lemma I and its palea encloses the staminate or sterile flower; lemma II and its palea encloses the fertile flower. Spikelets are elliptical, dorsally compressed, and acute. It has three anthers about 1.5 mm in length. The glume reaching apex of florets, thinner than fertile lemma; lower glume is ovate, 0.7-1.2 mm long, membranous, without keels, 1-3 veined. The lateral vein is absent in lower glume and its apex is acute. The upper glume is alsao ovate and without keel but larger than lower glume. It has 11-15 veined (Nandini *et al*., 2019).

Anthesis and Pollination: The opening of the spikelets commence from the second or third day after the appearance of the panicle. The flowering progresses from the top to the bottom of the panicle. The maximum numbers of flowers open on sixth or seventh day. It takes about fortnight to complete the flowering in a panicle. The anthesis occurs between 9.30 to 10 30 a.m. The glumes open for a short while and self pollination is the rule. The whole process of the anthesis is very rapid and is completed within 2-5 min. Emasculation and crossing techniques The knowledge of correct technique for crossing and selfing in various crops allow the breeder to obtain the combination of characters which are desired. This needs skill and practice before the worker can hope to accomplish best results. By recombining the alleles contributing for yield components like, tiller number, number of primary branches, number of secondary branches, number of grains per panicle and thousand grain weight. The removal of stamens or anthers or the killing of pollen grains of a flower without affecting in any way the female reproductive organ is known as emasculation. The purpose of emasculation is to prevent self-fertilization in the flowers of the female parent. In dioecious plants, male plants are removed, while in monoecious species the male flowers are removed to prevent self-pollination. But emasculation is essential in bisexual flowers. Naturally self-pollinated crops are shy pollinators with very poor movability to effect allogamy hence crossing is the technique where pollen from the desirable parent is dusted on the stigma of the seed parent. The main objective of the crossing is to create the variability and incorporate desirable traits such as high yielding, pest and disease resistance and important quality traits etc., in a single genotype and to widen the genetic base of the population (Nandini *et al.,* 2019).

GENETICS AND CYTOGENETICS

The chromosomes of hybrids of *Panicum sumatrense* and *P. psilopodium* pair almost perfectly with only a single quadrivalent, indicating that divergence between the two species may have initially occurred through a single reciprocal translocation. Hybrid plants are fertile and vigorous with non-shattering spikelets, and thus introgression of genes between the two species is common. This hybridization ability combined with its wide range of cultivation across India suggests that little millet was domesticated independently several times, although exact dates remain undetermined (Goron and Raizada, 2015). Little millet, one of the coarse cereals consumed as rice, is a self-pollinated, and tetraploid crop with chromosome number $2n = 4x = 36$ (Goron and Raizada, 2015; Nagaraja *et al*., 2023).

Little millet is a climate-resilient and high-nutrient value plant. The lack of molecular markers severely limits the adoption of modern genomic approaches in millet breeding studies**.** Using transcriptome data, a total of 4443 new SSR markers were developed, and the frequency, distribution, and function of these genic microsatellites were characterized. The unigenes containing microsatellites performed a spread spectrum of biological roles, the majority of which were related to thiamine metabolism, purine metabolism, other metabolic process, and signaling pathways. These findings shed light on the function of microsatellites in the transcriptome. Furthermore, the polymorphism and transferability of 24 eSSR markers were examined in 25 minor millet genotypes. The results of this research can present an excellent resource for germplasm identification, genetic relationship studies, linkage maps, MAS reproduction, and diversity analysis in little millet and other related species in future genetic and genomic studies, as well as play a substantial role to update the millet genic SSR markers database (**Desai** et al., 2021).

GENETIC DIVERSITY

Large phenotypic diversity has been observed for almost all the characters studied. Variation in panicle compactness and shape is depicted in Fig.6 Grain yield per plant, plant height and days to 50 per cent flowering recorded wide range indicating the extent of variability for these characters. There are accessions in the collection, which can flower as early as 49 days and as late as 83 days after sowing with a mean of 60 days. Plant height ranged from 88 to 142 cm with a mean of 111 cm. Number of productive tillers per plant varied from 3 to 26 with a mean of 6.9. Flag leaf length showed variation from 18 to 41 with a mean of 28.9 cm. Flag leaf width varied from 0.5 to 1.9 cm with a mean of 0.99 cm. Grain yield per plant showed a wide range of 2.9 to 50.1g with a mean of 13.8g. Among the traits studied grain yield per plant, number of productive tillers and total number of tillers showed higher variance. All the characters showed positive skewness indicating non- additive gene action (Fig. 7) (Nirmalakumari et al., 2010).

Fig. 6. Diversity for inflorescence compactness and shape of little millet germplasm

Fig.7 : Genetic diversity of seeds in Little millet

Evaluation of hundred and nine little millet germplasm accessions was done at Tamil Nadu Agricultural University, Coimbatore to study descriptive statistics, genetic variability, correlation and path analysis of yield and its components. High estimates of variability together with high heritability and high genetic advance were observed for grain yield, number of productive tillers per plant, total number of tillers per plant, flag leaf width and flag leaf sheath length indicated additive gene effects for these characters. Phenotypic selection based on these characters may be effective for yield improvement. Highly significant positive correlations of most of the component characters with grain yield and strong inter correlation among themselves indicated possibility of simultaneous improvement of these characters by selection. High positive direct effect and indirect effects of other characters through days to 50 per cent flowering indicated this character should be given importance in selection (Nirmalakumari *et al*., 2010). In a tribal area of the Indian Kolli hills, diversity among locally grown landraces of little millet was found to be high for all morphological traits measured both within and between landraces despite a small sampling area. High diversity, heritability and genetic advancement was observed in terms of yield and productive tillers in a collection of 109 landraces, meaning that the crop might be a good candidate for varietal development (Goron and Raizada, 2015). Sparse and irregular cultivation of little millet has an impact on the current level of genetic divergence. Genetic diversity is expressed as the genetic differences between species, sub species, varieties, populations or individuals. Species with greater genetic diversity are more likely to be able to evolve in response to a changing environment than those with low genetic diversity. Populations that lack genetic diversity may experience low fertility and high mortality among offspring even in the environments that are fairly stable. Genetic diversity analysis helps to identify the genetically varied genotypes for their use in breeding programmes. Genetic divergence based on morphological features could be assessed based on several techniques. One such technique is D^2 statistics developed by Mahalanobis, 1936. It is a multivariate analysis of grouping the genotypes into various clusters (Selvi *et al*., 2015).

A different collection of 460 accessions of little millet held by ICRISAT displayed genetic variation for most of the traits examined. A core collection of 56 genotypes was identified which was representative of the entire seed bank. Increased heritable lodging resistance has been introduced to a population of little millet with γ-ray mutational breeding (Goron and Raizada, 2015). Geneticdivergence among 30 little millet genotypes was evaluated based on 12 morphometric traits. Substantial variability among 30 genotypes was evident from theestimates of mean sumof square. Thirty little milletgenotypes formed 20 distinct clusters with high intercluster distances. Cluster mean confirmed the resultsof divergence analysis. Genotypesin cluster XXhadthe highest mean value for all the desirable traits.Single plant grain yield contributed the most to genetic diversity. The intra cluster distance was thehighest in cluster X (17.6). The highest inter cluster distance was noticed between clusters V and XX (210.5). The genotypes identified to be highly diversein the present study could be exploited in future breeding programs oflittle millet (Selvi *et al.,* 2015).

An investigation was carried out to assess the genetic parameters like variability, heritability and genetic advance,character association and path analysis for five yield component characters *viz*., plant height, number of productivetillers per plant, days to 50% flowering, days to maturity and grain yield per plot in 14 genotypes of little millet. The genetic parameters revealed that high PCV coupled with high GCV observed for number of tillers per plant, days to 50% flowering and grain yield per plot, while all the characters studied showed high heritability coupled with high genetic advance as per cent mean indicating the importance of additive gene action in governing the inheritance of these traits. Hence, simple selection is effective to improve the respected trait. Association studies revealed that, two out of five characters *viz*., days to 50% flowering and days to maturity exhibited highly significant positive correlation with grain yield per plot at phenotypic and genotypic levels. Path analysis studies revealed that days to 50% flowering and days to maturity showed true relationship by establishing significant positive association and positive direct effect on grain yield per plot both at genotypic and phenotypic levels, while plant height at genotypic level (Ashok *et al.,* 2016). Evaluation of 460 accessions of little millet held by International Crop Research Institute for Semi-arid Tropics (ICRISAT) revealed high genetic variation for most of the quantitative traits tested. In recent years, introduction of high-yielding varieties of other commercial crops such as cassava shifted to commercial production relegating cultivation of millets to an obscure background leading to genetic erosion of millet diversity. Mutation breeding was used as one of the strategy in addition to conventional breeding methods for genetic improvement of little millet. Mutation breeding was used as complement approach to conventional breeding methods for genetic improvement of little millet (Ganapathy, 2017). Evaluation of 460 accessions of little millet held by International Crop Research Institute for Semi-arid Tropics (ICRISAT) revealed high genetic variation for most of the quantitative traits tested (Ganapathy, 2017).

The extent of genetic variability present in any base population is most important for the success of breeding programme. Greater the variation in the material, better is the chance for selecting promising and desired types. Hence, thirty two genotypes of little millet were studied for genetic variability study at Hill Millet Research Station in randomized block design for different morphological and biochemical traits *viz*., days to 50 % flowering, days to maturity, zinc content (mg), plant height at maturity (cm), 1000 seed weight (g), fiber content (%), number of productive tillers per plant, Protein content (%), number of branches per panicle, ash content (%), panicle length (cm), fat content (%), grain yield per plant(g), calcium content (mg), straw yield per plant (g), iron content (mg). The results of the present study indicated all the sixteen characters had a wide range of variability in the different little millet genotypes. High estimates of genotypic and phenotypic variance were observed for days to 50% percent flowering, plant height at maturity, panicle length, straw yield per plant, days to maturity and calcium content. High genotypic and phenotypic coefficient of variation found in number of productive tillers per plant, grain yield and straw yield per plant. In the present study the high heritability coupled with high genetic advance was observed for number of productive tillers per plant, grain yield per plant, straw yield per plant, 1000 seed weight, protein content, ash content, fat content, calcium content, iron content and fiber content which, indicated that these characters are largely governed by additive genes and selection for improvement of such characters could be rewarding (Patel et al., 2018). Initially, 60 primers were screened among 32 genotypes of little millet from which 36 primers were selected on the basis of a sharp and clear banding pattern for final random amplified polymorphic DNA (RAPD) analysis. The PCR reaction was carried out using a single decamer primer at a time. In total, 175 RAPD marker loci were amplified of which 155 were polymorphic (88.58%). The band size of amplified markers was in the range 100–1900 bp. Ten bands were the maximum scored (for primer OPH-19) whereas two bands were the minimum scored (for primer OPC-13). On average, 4.86 bands per primer and 4.31 polymorphic bands per primer were recorded. The polymorphism information content ranged from 0.102 (OPAI-01) to 0.517 (OPE-04). A dendrogram divided the genotypes into two major and further into sub-groups according to their collection center geographical regions. This was the first report on molecular diversity analysis of a large collection of little millet germplasm. Diverse genotypes may be used in breeding programs for *P. sumatrense* improvement (Tiwari *et al.,* 2018).

Genetic and morphological variability parameters were studied for grain yield and its attributes with a set of 30 genotypes of little millet at Junagadh, Gujarat during Kharif 2017 in randomized block design with three replications under timely (E1), late (E2) and vey late sown (E3) conditions. The characters studied were days to 50 % flowering, days to maturity, number of productive tillers per plant, plant height, panicle length, grain weight per main panicle, grain yield per plant, biological yield per plant, harvest index, 1000 seed weight, chlorophyll content and specific leaf weight along with seven non metric characters viz., Plant growth habit, inflorescence shape, panicle compactness, grain color, lodging, grain shape and plant pigmentation were studied. Analysis of variance for each sowing date revealed highly significant differences among the genotypes for all the characters. The presence of highly significant differences established the existence of large variability among genotypes included in the experimental material. High GCV and PCV were observed for number of productive tillers per plant, biological yield per plant, harvest index and grain yield per plant for E1 and E2 environments, specific leaf weight for E2 and E3 environmental condition indicating broad genetic variability for these characters. Moderate estimates of PCV and GCV were observed for plant height in all environments. High heritability along with high genetic advance as per cent of mean observed for harvest index in all sowing conditions. Whereas, moderate heritability accompanies with moderate GAM was observed in plant height in all sowing conditions (Katara *et al*.,2019). Genetic diversity was estimated in 50 little millet genotypes by Mahalanobis D^2 analysis for nine quantitative and eight physiological traits. In the present investigation based on D^2 analysis fifty genotypes were grouped into 7 clusters. Among the different clusters cluster I had maximum number 35 genotypes followed by cluster II contains 10 and clusters III, IV, V, VI, VII were solitary. Inter cluster distances were higher than intra cluster distances indicating wider genetic diversity among the genotypes. The maximum inter cluster distance was observed between cluster IV and VII (131.19) followed by cluster II and IV (112.18) and cluster III and VII (104.28) indicated the existence of highly divergent genotypes. The genotypes from these clusters could be used as parents in hybridization programme to develop good recombinants. Days to 50% flowering, plant height, leaf area index at panicle initiation stage and 1000 seed weight contributed maximum towards genetic diversity. These traits could be given importance for selecting parents in crop improvement programme (Venkataratnam *et al.,* 2019). Millets are a diverse group of small-seeded grains that are rich in nutrients but have received relatively little advanced plant breeding research. Millets are important to smallholder farmers in Africa and Asia because of their short growing season, good stress tolerance, and high nutritional content. To advance the study and use of these species, we present a genome-wide marker datasets and population structure analyses for three minor millets: kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), and proso millet (*Panicum miliaceum*). We generated genome-wide marker data sets for 190 accessions of each species with genotyping-by-sequencing (GBS). After filtering, we retained between 161 and 165 accessions of each species, with 3461, 2245, and

1882 single-nucleotide polymorphisms (SNPs) for kodo, proso, and little millet, respectively. Population genetic analysis revealed 7 putative subpopulations of kodo millet and 8 each of proso millet and little millet. To confirm the accuracy of this genetic data, we used public phenotype data on a subset of these accessions to estimate the heritability of various agronomically relevant phenotypes. Heritability values largely agree with the prior expectation for each phenotype, indicating that these SNPs provide an accurate genome-wide sample of genetic variation. These data represent one of first genome-wide population genetics analyses, and the most extensive, in these species and the first genomic analyses of any sort for little millet and kodo millet (Johnson *et al.,* 2019).

The experiment was conducted during *Kharif,* 2019-20 with 32 germplasm accessions of little millet to study genetic diversity for yield and yield contributing traits at Hill Millet Research Station, Waghai, Dangs, Gujarat in a randomize block design. The observations for nine morphological traits were recorded and principal component analysis was done. Principal component analysis indicates that three principal components PC-1, PC-2, PC-3 and PC-4 explains 58.40%, 43.53%, 5.21% and 1.21%, respectively of the total variation. The first principal component had showed positive loading for PT (productive tillers per plant) and HI (harvest index). The second principal component had positive loading for days to 50% flowering (DF), days to maturity (DM), productive tillers per plant (PT), grain yield per plant (GY), straw yield (SY) and harvest index (HI). The third principal component had positive loading for DM, PT, GY, SY and HI. While, the fourth principal component had positive loading for PH, PT, GY and HI. The results of principal component analysis utilized in the study have revealed the high level of genetic variation and the characters contributing for the variation was identified. Hence, the genotypes of this population can be utilized for trait improvement in little millet breeding programs using the traits contributing for major variation (Ladumore *et al.,* 2021). The existence of variability is essential for resistance to biotic and abiotic factors as well as for wider adaptability in different set of environment. Variability results due to differences either in the genetic constitution of the individuals of a population or in the environment in which they are grown. Selection is also effective when there is presence of large genetic variability among the individuals in a population. Hence, insight into the magnitude of genetic variability present in a population is of paramount importance to a plant breeder for starting judicious crop improvement programs (Ladumore *et al*., 2021).

BREEDING

Germplasm

A different collection of 460 accessions of little millet held by ICRISAT displayed genetic variation for most of the traits examined. A core collection of 56 genotypes was identified which was representative of the entire seed bank. Increased heritable lodging resistance has been introduced to a population of little millet with γ-ray mutational breeding (Goron and Raizada, 2015). In little millet, a total of 2,632 accessions have so far been collected from various parts of the country. Among these, 1,887 accessions had passport data with locality details of collection sites (state, district and village) and these were further screened for availability in the National gene bank. Geo-referencing and mapping of collected diversity of little millet germplasm was done. Analyses of passport data shows that majority of little millet germplasm accessions have been collected from Andhra Pradesh (574) followed by Madhya Pradesh (240), Tamil Nadu (198), Odisha (175), Maharashtra (150), Chhattisgarh (133), Gujarat (83), Himachal Pradesh (71) and Jharkhand (66) while minimum accessions were collected from Arunachal Pradesh (3), Rajasthan (3) and Meghalaya (4) (Semwal *et al*., 2021) (Table 2).

Out of total 1,887 accessions with locality information 1,005 accessions were conserved in National Gene Bank. Maximum accessions were conserved from Andhra Pradesh (307) followed by Madhya Pradesh (190), Maharashtra (96), Odisha (77), Tamil Nadu (63), Bihar (59), and Gujarat (54), (Table 9). However, there is a gap between collected and conserved germplasm particularly from Andhra Pradesh, Madhya Pradesh and Tamil Nadu (Semwal et al., 2021). Andhra Pradesh: A total of 574 accns. of little millet have been collected from eight districts of Andhra Pradesh which was checked, corrected, geographic coordinates added and analyzed for diversity mapping. Maximum accessions have been collected from Visakhapatnam (199) followed by Vizianagram (47), Cuddapah (30), Srikakulam (25), Anantpur (22), East Godavari (14) and Prakasam (10) districts. Of which 353 acc. having locality information were mapped to identify gaps in collection and conservation. A total of 307 accessions are under LTS in Genebank. Germplasm has not been conserved from remaining six districts. 4.3.2 Madhya Pradesh: Passport data of 240 little millet accns. collected from 23 districts of Madhya Pradesh was checked, corrected, geographic coordinates added and analyzed for diversity mapping. Districtwise germplasm collections were made from Shahdol (44), Dindori (29), Singrauli (22), Rewa (21), Anuppur (10) and Betul (6) districts. Out of these 64 acc. having locality information were mapped to identify gaps in collection and conservation. A total of 190 accessions are conserved in NGB (Semwal et al., 2021). A total of around 463 landraces have been collected with maximum collection from Madhya Pradesh (140) followed by Andhra Pradesh (95), Maharashtra (66), Gujarat (37) and Chhattisgarh (30). Some of the landraces collected from various states are as follows; Aarlu, Arikelu, Samalu, Chikma, Kutki, Cheena, Kutki, Samai etc (Annex.-I) 4.5 Gaps identified for future collection from different states of the country included Chhattisgarh (Bastar, Bijapur, Naryanpur and Kondagaon); Gujarat (Tapi and The Dangs); Odisha (Nabrangpur, Naupada, Kalahandi and Balangir) and Karnataka (Dharwad, Belgaum and Chikakmagluru) (Semwal *et al.,* 2021). All India Coordinated Minor Millet Project (AICMMP), Bengaluru, has 544 accessions, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, has 466 accessions and USDA Agricultural Research Service (USDA-ARS), Griffin, USA has 212 accessions of little millet (Goron and Raizada, 2015).

Breeding: Various breeding methods such as pure line selection, pedigree selection, mass selection, and mutation breeding, which are applicable to self-pollinating crops are followed in small millets as well. Reports on small millets cultivars released over a period of time shown that a majority of them were released following selection from local landraces/cultivars, followed by pedigree selection (hybridization and selection). For example, in India 20 varieties of little millet were released following selection from landraces, through pedigree selection, and mutation breeding. In general, mutation breeding has played a key role in self-pollinated crops where hybridization is very difficult to create variability. Mutation breeding has resulted in the release of 2 varieties of little millet in India (Vetriventhan et al., 2020). The All India Coordinated Small Millets Improvement Project was established in the year 1986 with head quarters at University of Agricultural Sciences, Bangalore and with 14 centres spread over the country to address research needs of small millets. 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. The research in the project is focused to state / regional needs from the point of developing appropriate agro production technology for maximizing production / productivity. The work is multi□disciplinary and applied in nature. 20 varieties in little millet (6 in pre and 14 in post coordinated project era respectively) have been released **(Table 3)** (Seetharam, 2014): Mutation breeding was used as one of the strategy in addition to conventional breeding methods for genetic improvement of little millet. Mutation breeding was used as complement approach to conventional breeding methods for genetic improvement of little millet (Ganapathy, 2017).

Table 2. Little millet germplasm collected from different States

States	Accns. collected	Accns. in NGB	Operational gaps
Andhra Pradesh	574	307	267
Madhya Pradesh	240	190	50
Tamil Nadu	198	63	135
Odisha	175	77	98
Maharashtra	150	96	54
Chhattisgarh	133	51	82
Jharkhand	66	8	58
Bihar	63	59	4
Gujarat	83	54	29
Himachal Pradesh	71	24	47
Karnataka	44	32	12
West Bengal	19	19	0
Telangana	18	3	15
Uttarakhand	14	14	0
Kerala	11	-	11
Arunachal Pradesh	3	1	2
Rajasthan	3	2	1
Meghalaya	2	-	2
Punjab	1	1	0
Uttar Pradesh	10	1	9
Others	754	3	751
Total	**2,632**	**1,005**	**1627**

Table 3. No of varieties released from various selection methods in different small millets

SelectionMethod	Little millet
Pure lineselection	18
BulPedigreemethod	1
MutationBreeding	1
Total	**20**

Varieties: Improved varieties of little millet with pedigree and recommende zone are given in **Table 4** (Seetharam, 2014).

Table 4. Improved varieties of little millet

Name of the variety	Pedigree	Year of release	Maturity	Average yield	Recommended domain
Paiyur 2	Pure line selection	2000	95-100	800-1000	Tamil Nadu
Kolab (OLM 36)	Mutant of SS 81-1	2001	95-100	2800-3000	MP, Odisha, Chattisgarh, Bihar, Karnataka, Gujarat
Tarini (OLM 203)	Selection from KL 2	2001	105-110	2500-3000	Odisha, AP, Bihar, TN
Sabara (OLM 20)	Mutant of SS 81-1	2003	75-80	1100-2000	All little millet growing areas of the country
Co 4	Co 2 x MS 1684	2005	75-80	1600-2000	Tamil Nadu
JK 36	Pure line selection	2009	75-80	1000-1200	Madhya Pradesh
Soura (OLM 208)	Pure line selection	2009	100-105	1400-1500	Odisha, Gujarat, Chattisgarh
OLM 217	Pure line selection	2009	105-110	1500-1600	Odisha, Gujarat, Chattisgarh

Varieties of little millet are given in **Table 5** (Dhan, 2014).

Table 5. Varieties of little millet

1.	OLM 217
2.	OLM 208
3.	JK 36
4.	Co 4 (TNAU 91)
5.	OLM 20 (Sabara)
6.	OLM 203 (Tarini)
7.	OLM 36 (Kolab)
8.	Paiyur 2
9.	TNAU 63 (Sukshema)
10.	Birsa Gundli 1
11.	Co 3
12.	Paiyur 1
13.	JK 8
14.	JK 2 (Dindori 2)
15.	PRC 3
16.	K1
17.	Gujarat vari 1
18.	Co 2
19.	Dindori 1
20.	Co 1

State-wise recommended varieties of little millet are given in Table 6 (Maitra and Shankar, 2019).

Table 6. State-wise recommended varieties of littlemillet

State	Varieties
AndhraPradesh	OLM 203, JK 8, BL-6, DHLM-36-3
Chattisgarh	JK 8, BL 6, JK-137, BL-4, JK 36, DHLM-36-3
Gujarat	GNV 3, Gujarat GV 2, GV 1, OLM 203, JK 8,BL-6, DHLM-36-3, DHLM14-1
Karnataka	OLM 203, JK 8, BL-6, DHLM-36-3, DHLM-14-1
MadhyaPradesh	JK-4, JK 8, JK 36, JK-137, BL-6, DHLM-36-3
Maharashtra	Phule Ekadashi, JK 8, OLM- 203, BL-6,DHLM-36-3, DHLM-14-1
Orissa	OLM- 203, OLM -208, OLM-217, BL-6,DHLM-36-3, HLM-14-1
Tamil Nadu	Paiyur 2, TNAU 63, CO 2, CO 3,C0-4,K1, OLM -203, OLM -20, BL-6, DHLM-36-3,DHLM-14-1

A number of varieties with high yield potential have been released for different states. The list of latest and popular varieties recommended for different states are given in **Table** 7 (Vikaspedia, 2020).

Table 7. Popular varieties recommended for different states

State	Varieties
Orissa	OLM 203, OLM 208, OLM-217
Madhya Pradesh	JK-4, JK 8 and JK 36
Andhra Pradesh	OLM 203, JK 8
Tamil Nadu	Paiyur 2, TNAU 63 and CO 3,C0-4,K1, OLM 203,OLM 20
Chattisgarh	JK 8, BL 6, BL-4, JK 36
Karnataka	OLM 203, JK 8
Gujarat	GV 2, GV 1, OLM 203, JK 8
Maharashtra	Phule Ekadashi, JK 8, OLM 203

Table 8. Salient features of released varieties of little millet in India

Name of variety	Pedigree	Institute where developed	Year of release	Maturity (days)	Av. Yield (Q/ha)	Area of adaptation	Special features
BL 6	Paiyur 1 x OLM 29	Jagdalpur IGKVV, Raipur	2016	90-95	12-14	National	Recommended for upland cultivation, and rich in zinc and calcium
DHLM 36-3	Co-4 x Paiyur – 2	ARS, Hanumanmatti, UAS, Dharwad	2016	95-100	14-16	National	Late maturing variety
Chhattisgarh Kutki-2 (BL-4)	CO-2 x TNAU 97	Jagdalpur IGKVV, Raipur	2016	90-95	10-12	Chhattisgarh	It has high iron content (28.3 mg/100 g grain). Tolerant to major pests.
GV-2	Derivative from mutant of released variety 'Gujarat Vari -1'	Waghai, NAU, Navsari	2016	115-125	26-28	Gujarat	Clean White colour and bold seeded, Resistant to pest and diseases.
Phule Ekadashi(KOPLM 83	Selection from local germplasm	ZARS, Kolhapur, MPKV rahuri	2016	120-130	12-14	Sub-montane and Ghat Zone of Maharashtra	Non- lodging.
JawaharKutki 4 (JK 4)	DLM 42 x Kutki 1	Rewa JNKVV Jabalpur	2016	75-80	13-15	Rainfed areas of Madhya Pradesh	Suitable for sole as well as inter/mixed cropping, responsive to NPK, resistant to drought, lodging, and key pest Shoot fly and moderately resistant to head smut
JK 36	Selection from local Shahdolgermplasm	Rewa, JNKVV, Jabalpur	2009	75-80	10-12	M.P. state	Tolerant to shootfly
OLM 208	Selection from Lajigada local	OUAT, Berhampur	2009	100-105	12-15	National	Moderately resistant to shootfly
OLM 217	Selection from Udayagiri local	OUAT, Berhampur	2009	105-110	15-16	National	Resistant to rust and grain smut, but moderately resistant to sheath blight, tolerant to shootfly
Co 4	Co 2 x MS 1684	TNAU, Coimbatore	2005	75-80	16-20	Tamilnadu	Non-lodging, suitable for double cropping.\
OLM 20	Mutant of SS-81-1	OUAT, Odisha	2003	75-80	11-12	Odisha, Madhya Pradesh, Chattisgarh	Drought tolerant
Tarini(OLM 203)	Selection from local cultivar (KL 2) of Koraput Dist.	OUAT, Berhampur, Odisha	2001	105-110	10-11	Karnataka, Andhra Pradesh, Odisha, Bihar, Tamil Nadu	Resistant to blast and grain smut
Kolab (OLM 36)	Mutant of SS-81-1	OUAT, Odisha	2001	95-100	10-11	Madhya Pradesh, Odisha, Chattisgarh, Bihar, Karnataka, Gujarat	Resistant to brown spot and sheath blight
Paiyur 2	Pure line selection from accession PM 295	TNAU, Coimbatore	2000	95-100	7.5-8.5	Tamil Nadu	Late maturity
TNAU 63	Selection from germplasm MS 2369	TNAU, Coimbatore	1997	90-100	11-12	Tamil Nadu, Karnataka, Gujarat	High grain and fodder yield
BirsaGundli 1	Selection from Local	BAU, Ranchi	1993	55-60	7-8	Bihar Plateau, Jharkhand	Early maturity
Paiyur 1	Pure line selection	RRS, Paiyur, TNAU	1989	90-95	8-10	Tamil Nadu	Late maturity

Table 9: Improved little millet varieties released in India

Variety	Year of release	Maturity (days)	Av. yield (q/ha)	Area of adaptation	Special features
Kalinga Suan 217 (OLM 217)	2021	105-110	15-16	Odisha	Resistant to rust and grain smut, moderately resista sheath blight, tolerant to shootfly
Chhattisgarh Sonkutki (BL-41-3)	2021	95-100	16-19	Chhattisgarh	Early maturing, suitable for millet-niger, millet-horse and millet-urdbean cropping system, tolerant to rus sheath blight
CLMV 1 (Jaicar Sama 1)	2020	98-102	15-17	Maharashtra, Andhra Pradesh, Telangana, Tamil Nadu, Puducherry	Tolerant to shoot fly, banded blight, leaf blight and t spot diseases, high grain iron (58.8 ppm), zinc (35 p and protein (12.8%)
ATL-1 (TNPsu 177)	2019	85-90	-	Tamil Nadu	Early maturity, bold grains with high bulk density, to to drought, shoot fly, grain smut and sheath blight
GNV-3	2018	110-115	28-29	Gujarat Zone-I, II & III	Bold seeded, multi-tillering, non-lodging, resistant t smut and sheath blight, high in minerals and crude
DHLM-14-1	2018	97-99	16-17	Tamil Nadu, Karnataka, Gujarat, Maharashtra and Odisha	Tolerant to shoot fly
DHLM 36-3	2018	95-100	14-16	Karnataka	Late maturing
BL 6	2016	90-95	12-14	All states	Suitable for upland cultivation, rich in zinc and calci
Chhattisgarh Kutki-2 (BL 4)	2016	90-95	10-12	Chhattisgarh	High iron content, tolerant to major pests
GV-2	2016	115-125	26-28	Gujarat	White and bold seeds, resistant to pest and disease
Phule Ekadashi (KOPLM 83)	2016	120-130	12-14	Sub-mountainous and Ghat zone of Maharashtra	Non-lodging
Jawahar Kutki 4 (JK 4)	2016	75-80	13-15	Rainfed areas of Madhya Pradesh	Resistant to drought, lodging, Shoot fly, moderately resistant to head smut

USES

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, rotiand 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 (Bhat *et al.,* 2018). Seeds of these millets are very small but easy to harvest and very nutritious. They are eaten cooked or ground into a powder and used for making cakes etc. They can also be sprouted and used in salads. The seed can be cooked whole, and becomes very gelatinous, but it is rather difficult to crush all of the small seeds in the mouth and thus, some of the seed

will pass right through the digestive system without being assimilated. The flowers are used as a food coloring in ceremonial maize bread (Saloni *et al*., 2018).

Little millet has been a staple in traditional culinary practices across various cultures. It is commonly used to prepare dishes like porridge, upma, and pulao. The grains are often roasted to enhance their nutty flavour before being cooked. Little millet's small size and quick cooking time make it convenient for everyday meals. These traditional methods of cooking little millet have been passed down through generations, showcasing its cultural significance and culinary versatility. Little millet's versatility shines through its ability to be incorporated into various dishes. It may replace rice or other grains in pilafs, salads, soups, and desserts. Little millet recipes range from traditional upma and pulao to innovative creations like stuffed bell peppers and kheer. Its adaptability allows for the exploration of diverse flavours and textures, making little millet an excellent choice for those seeking culinary experimentation while reaping its nutritional benefits **(Fig. 8)** (Nutritionfact, 2023).

Tips for Cooking Little Millets (Distacart, 2020).

Before we talk about cooking, let's talk about storing the grains. Store millet grains in airtight containers to store them for up to 6 months. You can increase the longevity of these grains by keeping them in a freezer.

A few cooking tips to prepare meals using Little Millets are:

- As Little millets are tiny in size, they can be easily mashed by softening them down by adding boiled water.
- You can even pop the millets to have it eaten like popcorns.
- Loose the starch to avoid stickiness while cooking by soaking them in couple cups of water beforehand
- Cook millets in containers with a lid to minimize the use of gas or electricity
- To enhance the nutty flavor of the grain, toast it in a skillet before adding water/stock.
- You can use **millets** to thicken soups too.

		
Dosai	**Idlis**	**Lemon Rice**
		
Upama	**Payasam**	**Porridge**
		
Mixture	**Cutlets**	**Drinks**
		
Barfi	**Puri**	**Little millet + Cashew biscuits**

Sweet pops

Vermicelli

Porridge

Flour

Rawa

Flakes

Fig. 8: Products from Little millet

Recipes and Meal Ideas Incorporating Little Millet (Nutritionfact , 2023)

Little Millet Salad: Combine cooked little millet with colourful vegetables, herbs, and a zesty dressing for a refreshing and nutritious salad.

Little Millet Upma: Prepare a flavorful upma by sautéing onions, vegetables, and spices and then adding cooked little millet.

Little Millet Pulao: Cook little millet with aromatic spices, vegetables, and broth to create a flavorful and wholesome pulao.

Little Millet Kheer: Simmer cooked little millet in milk with sugar, cardamom, and nuts for a delicious and nutritious dessert.

Little Millet Stuffed Bell Peppers: Fill bell peppers with a savoury mixture of cooked little millet, vegetables, and spices, and bake until tender.

The options are infinite. Little millet adds flavour and texture to savoury and sweet meals without sacrificing health. Experimenting with little millet opens up a world of culinary innovations and nourishing meal options. Now let's dive into our main section on little millet benefits.

NUTRITIONAL VALUE

Nutritional information on little millet (per 100g of raw millet) are Protein (g) 9.7, Carbs (g) 67, Fat (g) 4.7, Fiber (g) 7.6, Calcium (mg) 17, Phosphorus (mg) 220, Iron (g) 9.3 and Energy (Kcal) 329 (Jhawer, 2017). Little millet is fibrous millet, next to barnyard millet. According to research, some varieties of kodo millet and little millet have been reported to have 37% to 38% of dietary fiber, which is the highest among the cereals. Fiber helps maintain sound digestion and satiates hunger quickly. Like foxtail millet and barnyard millet, little millet is also high in Iron. Little millet is high in fat, comprising majorly of the healthy polyunsaturated fatty acids (PUFA). The flavonoids present in the little millet act as antioxidants and play many roles in the body's immune defence system. Although little millet is high in protein, it has a poor amino acid composition (Jhawer, 2017). It is one of Little millet is comparable with other cereal grains such as rice and wheat as a source of protein, fat, carbohydrates and crude fibre, apart from minerals and vitamins. It also contains phytochemicals,such as phenolic acids, flavonoids, tannins and phytate(Saloni *et al.,* 2018).

Table 10 shows composition of littlemillet per 100 g edible portion (Saloni *et al.,* 2018)

Table 10. Composition of little millet per 100 g edible portion

Sr. No.	Ingredients	Quantity/100 g
1.	Water	9.8 g
2.	Protein	14.5 g
3.	Fat	6.5 g
4.	Carbohydrate	66.29 g
5.	Crude fibre	15.2 g
6.	Calcium	153 mg
7.	Magnesium	266 mg
8.	Phosphorus	455 mg
9.	Iron	7.6 mg
10.	Zinc	3.2 mg
11.	Thiamine	0.08 mg
12.	Riboflavin	0.21 mg
13.	Niacin	1.29 mg
14.	Vitamin B_6	0.22 mg
15.	Folate	49 µg
16.	Ascorbic acid	3.7 mg
17.	Tryptophan	181 mg
18.	Lysine	747 mg
19.	Methionine	226 mg
20.	Phenylalanine	542 mg
21.	Threonine	558 mg
22.	Valine	679 mg
23.	Leucine	879 mg
24.	Isoleucine	582 mg
25.	Linoleic acid	2834 mg
26.	Oleic acid	1433 mg
27.	Palmitic acid	1284 mg
28.	Stearic acid	220 mg
29.	Energy	1565 kJ (374 kcal)

According to Bhat *et al.* (2018) little millet grain contains Carbo-hy-drates (g) 65.5, Protein (g) 10.1, Fat (g) 3.89, Energy (Kcal) 346, Dietary fibre (g) 7.7, Ca (mg) 16.1, P (mg) 130, Mg (mg) 91, Zn (mg) 1.8, Fe (mg) 1.2, Thiamin (mg) 0.26, Ribo-flavin (mg) 0.05, Niacin (mg) 1.3, Folic acid (µg) 36.2. Like other small millets, little millet is also rich in nutrients. Each 100 g little millet grain contains 65.5 g carbohydrate, 10.1 g protein, 3.89 g fat, 346 Kcal energy, 7.7 g dietary fibre, 16.1 mg calcium, 130 mg phosphorus, 91 mg magnesium, 1.8 mg zinc, 1.2 mg iron, 0.26 mg thiamin, 0.05 mg riboflavin, 1.3 mg niacin and 362 µg folic acid (Maitra and Shankar, 2019). Little Millet is a traditional crop in India which is widely famous among people who are health conscious as these tiny grains are packed with a great number of nutritious substances. *Little Millets* are gluten-free, non-acid-forming, and a perfect addition to the diet of people who do yoga, workouts, cardio. Moreover, its high nutritional value makes it a must-eat in a balanced diet. However, we should never eat an excess of something just because it is good because excess little millet usage in diet can lead to various side effects. *Little Millets* are a whole grain option that is low in carbohydrates and helps in improving glucose metabolism. Glucose in our body can be regulated as the little millet usage slowly releases sugar in our bloodstream, minimizing the absorption of glucose. Thanks to the presence of dietary fiber and resistant starch, little millets also exhibit properties like hypoglycemic as well as hypolipidemic effects (Distacart, 2020).

Table 11. Nutritional value of 100g serving of little millets

Protein	9.7 g
Carbohydrates	60.9 g
Fat	5.2 g
Iron	9.3 mg
Phosphorus	220 mg
Calcium	17 mg
Magnesium	114mg
Energy	329 kcal
Crude Fibre	7.6 g
Ash	5.4 g
Thiamin	0.30 mg
Riboflavin	0.09 mg
Niacin	3.2 mg

A detailed mapping of the nutritional value of 100g serving of millets is given in Table 11 (Distacart, 2020): Little millet is a marvellous source of protein (10.13%), carbohydrates (65.55%), fat (3.89%), fiber (7.72%), iron (1.26 mg/100g), phosphorous (130 mg/100g), zinc (1.82 mg/100g), magnesium (91.41 mg/100g), niacin (1.29 mg/100g) and polyphenols making it a vital option for nutritional security.

Magnesium helps to improve heart health, niacin to lower cholesterol, phosphorus in fat metabolism, body tissue repair and energy production. Little millet contains amino acids in balanced proportions and is rich in methionine, cysteine and lysine. It is specifically beneficial to vegans dependent on plant foods for protein (Neeharika *et al*., 2020). Little millets are fibrous which is next to barnyard millets. According to a researcher some varieties of kodo millets and little millet have 37 -38% of dietary fiber, which is the chief among cereals. Little millets are high in fats which comprises healthy polyunsaturated fatty acids. The flavonoids present in little millets play important role in self-defence and the immune system. Although it content high amount of protein, it has poor amino acid composition (Indirani and Devasena, 2021). Millets are excellent sources of antioxidants like polyphenols, phenolic compounds, tannins, flavonoids play an important role in promoting health by combating lifestyle diseases such as diabetes, cardiovascular disease, obesity, cataract, cancers, inflammation, and gastrointestinal problems which are major problems currently faced by our country. The polyphenols are the biggest group of phytochemicals exhibiting antioxidant, metal chelating, and reducing powers. These antioxidants presented in little millet contribute to health, delay aging, reduce metabolic syndrome and improve the immune system. The bioactive properties of polyphenols include anticarcinogenic, anti-inflammatory, antiviral, and neuroprotective activities (Indirani and Devasena, 2021).

Nutrient composition of little millets (per 100g) is given in Table 12 (Indirani and Devasena, 2021).

Table 12. Nutrient Composition of Little Millets (per 100gm)

Nutrients	Little Millet
Carbohydrates (gm)	67
Protein (gm)	7.7
Fat (gm)	4.7
Energy (gm)	341
Crude Fibre (gm)	7.6
Mineral Matters (gm)	1.5
Calcium (mg)	17
Phosphorous (mg)	220
Iron (mg)	9.3

Nutritional value of little millet is given in Table 13 (Prakash, 2023).

Table 13: Nutrition profile of little millet	
Carbohydrates (g) :	67.0
Protein (g) :	7.7
Fat (g) :	4.7
Energy (KCal) :	341
Crude fiber (g) :	7.6
Calcium (mg) :	17.0
Phosphorous (mg) :	220.0
Iron (mg) :	9.3

Nutrient composition of little millets (per 100g) is given in Table 12 (Indirani and Devasena, 2021). It is composed of protein, vitamins, carbohydrates, and minerals. A balanced amino acid profile is seen in proteins, besides being a good source of methionine, lysine, and cystine as well (Nagaraja *et al*., 2023). Little millet is also packed with iron and fibre (Vincent, 2023). The Little millet or samai in reality is large in nutrition. Finger millet is the richest source of calcium (300-350 mg/100 g) and other small millets are a good source of phosphorous and iron. The protein content ranges from 7 to 12% and fat content from 1 to 5.0%. The millet protein has a well-balanced amino acid profile and a good source of methionine, cystine, and lycine. These essential amino acids are of special benefit to those who depend on plant food for their protein nourishment. The millet grain contains about 65% carbohydrate, a high proportion of which is in the form of non-starchy polysaccharides and dietary fiber. Finger Millet grains are also rich in important vitamins viz., Thiamine, riboflavin, folic, and niacin (Indianmed, 2023). Little millet is a nutritious and gluten-free grain that is widely consumed in various parts of Asia, especially in India. Little millet nutritional value per 100g is given in Table 14 (Nutritionfact ,2023).

Table 14. Little millet nutritional value per 100g

Nutrient	Amount per 100g
Calories	378 kcal
Carbohydrates	60.9 grams
Protein	9.7 grams
Fat	5.2 grams
Fibre	7.6 grams
Calcium	17 mg
Iron	9.3 mg
Thiamine (B1)	0.30 mg
Riboflavin (B2)	0.09 mg
Niacin (B3)	3.2 mg

HEALTH BENEFITS

According to Jhawer (2017) following are the health benefits of little millet:

Good source of potent antioxidants: Millet's antioxidants such as polyphenols, phenolic compounds, tannins, flavonoids are not directly related to nourishing the body, but play an important role in promoting health by helping in diseases such as diabetes, cardiovascular disease, cataract, cancer, inflammation and gastrointestinal problems. Polyphenols are the biggest group of phytochemicals that have been found in plant-based foods and have been linked to various health benefits. They are considered as "life span essential" due to their role in maintaining health throughout end phase of life. It has been reported that soluble- and insoluble-bound phenolic extracts of several varieties of millet are rich sources of phenolic compounds. They exhibit antioxidant, metal chelating, and reducing powers. Furthermore, effects of germination, steaming,

and roasting on the nutraceutical and antioxidant properties of little millet were investigated. The results showed that the total phenolic, flavonoid, and tannin contents of processed little millet increased to a fair amount, compared to the native sample indicating that processing has beneficial effects on the nutraceutical and antioxidant properties of little millet. A recent research published in the *Proceedings of the Nutrition society*, (2017) mentions the millet grains to be richer in polyphenol and antioxidant content compared to millet flour and flakes. The study represents a starting point for the future human studies, which will look at the effect of polyphenol-rich millet products on glycemic response.

Acts as a nutraceutical: Little millet has received very little attention from plant breeders as a crop source. The millet is a promising food ingredient suitable for large scale utilization as processed products, snacks, baby foods and also play a major role in propagating food security among underdeveloped and developing countries. It stands out to be one of our "indigenous super foods". The cases of obesity and diabetes are increasing fast globally. Food containing complex carbohydrates with high fiber and health beneficial phytochemicals has been in demand to combat health issues. Awareness about the whole grain foods is increasing worldwide because they are rich sources of phytochemicals and dietary fiber. Phytates, polyphenols and tannins of millet's foods can contribute to antioxidant activity that play important role in health, aging and metabolic disease.

Millets can be termed as "food medicine".

Helps combat diabetes: High carbohydrate diet can increase plasma glucose, leading to insulin resistance. Little millet is a low glycemic index food, which is a good source of slow digesting carbohydrates and dietary fiber. It takes longer for glucose to enter the bloodstream and hence blood sugar levels are stable. This proves to be beneficial for diabetics who have to control rapid rise and decline of glucose in the blood.

Other benefits of little millet: Little millet contains magnesium which can helps improve heart health. Vitamin B3 (niacin) in little millet helps lower cholesterol. Little millet is also a good source of phosphorus which, helps with fat metabolism, body tissue repair and energy production.

Health Benefits of Little Millets (**Distacart, 2020**).

Little millet benefits in nourishing our body and boosting our immunity. These are also rich in antioxidants like phenolic compounds, flavonoids, tannins, and polyphenols, which helps in keeping human bodies safe from ailments like cardiovascular diseases, cataracts, cancers. Recent studies undertaken by Proceedings of the Nutrition Society, 2017, have found out that unprocessed millet grains are richer in nutritious value than millet flours or millet flakes. Moreover, being suitable for all age groups, little millet usage can be incorporated in baby foods, snacks, processed food items. The high inclusion of dietary fibers in these little wonders also makes us feel full with a little portion. In this way, our frequency of eating can also be regulated. The regulation of glucose absorption leads to the prevention of diabetes. The presence of magnesium makes it an impenetrable shield against heart diseases; niacin lowers cholesterol, and phosphorus helps in metabolizing fats and facilitates the production of energy.

According to Neeharika *et al*. (2020) the following are the.**health benefits of little millet:** There is a great scope of using little millets in combating nutritional disorders and can provide adequate nutrition to various segments of the society. The health consequences of overweight and obesity contributed to an estimated 4.0 million deaths (7.1% of all deaths) and 120 million healthy years of life lost as disability-adjusted life years (DALYs) globally (4.9% of all DALYs among adults). The poor diets are the second-leading risk factor for deaths and DALYs globally contributing to 18.8% of deaths among which 50.0% due to cardiovascular diseases.

Combat lifestyle diseases: Little millets with low carbohydrate content, slow digestibility, low glycaemic index and water-soluble gum content improve glucose metabolism. Millet polyphenols inhibit the activity of digestive enzymes like amylase, glucosidase, pepsin, trypsin and lipases in the body. The grains release sugars slowly into the blood and delay glucose absorption from intestines due to α-amylase inhibition. The dietary fiber and resistant starch in minor millets exhibit hypoglycaemic and hypolipidemic effects by inducing carbohydrate tolerance, satiety, weight loss and prolonged gastric emptying. Hence little millets are recommended for people with lifestyle diseases like obesity, diabetes and cardiovascular conditions.

Good source of potent antioxidants: Millets are rich in antioxidants like polyphenols, phenolic compounds, tannins, flavonoids play an important role in promoting health by combating lifestyle diseases such as diabetes, cardiovascular disease, obesity, cataract, cancers, inflammation and gastrointestinal problems which are on the rise. The polyphenols are biggest group of phytochemicals exhibiting antioxidant, metal chelating and reducing powers. These antioxidants contribute to health, delay aging, reduce metabolic syndrome and improve immune system. The bioactive properties of polyphenols include anticarcinogenic, anti-inflammatory, antiviral and neuroprotective activities.

Nutraceutical properties: The cases of obesity and diabetes are increasing fast globally due to devouring on empty calories rich and highly processed foods. The whole grain foods containing complex carbohydrates with high fiber and health beneficial phytochemicals have been in demand to combat health issues. Little millets provide significant amount of bioactive nutraceutical components such as phenols, tannins, phytates, γ-aminobutyric acid (GABA), carotenoids and tocopherols that play important role in health, aging and metabolic disease. Henceforth they are considered as nutricereals. Furthermore, germination, malting, steaming and roasting of little millets have beneficial effects on the nutraceutical and antioxidant properties by improving total phenolic, flavonoid and tannin contents. Germination is known to enhance the digestibility of little millets, improve the availability of amino acids, mono, di and oligosaccharides, fatty acids, soluble dietary fiber and bio-accessible minerals along with reducing antinutritional factors.

According to Indirani and Devasena (2021) the health benefits of little millet are as follows:.
Helps to fight against diabetes: Little millet is a low glycaemic indexed food because the high content of fiber makes the digestion of carbohydrates a slow process. It takes a long time for glucose to enter the blood and maintains the blood sugar level.

Cataract genesis inhibition: Western countries are facing a major issue of blindness due to retinopathy and cataract worldwide. In diabetes patients there will be an accumulation of sorbitol. This accumulation is mediated by the key enzyme known as aldose reductase. It is present in little millet. This reduces the risk of developing cataracts.

Cancer-fighting millets: The chief grain of India is millet which is versatile, gluten-free, whole grain of India that is similar to quinoa. Small millet is a nutritional powerhouse and excellent source of protein, fibre, B vitamins, iron, zinc, phosphorous, and magnesium. Chemotherapy and

radiation therapy can be exhausting the energy and the body needs the power to go through each treatment. So, these little millets contain an enormous number of anti- oxidant and phenolic compounds which detoxifies the body from therapy. This grain rectifies the conditions like asthma and bronchitis

Improves heart health: Since it is excellent in magnesium, it maintains steady blood pressure and heart rate. Magnesium is a mineral, that is essential for hundreds of biochemical reactions in which happen in the body. This grain samai is also fighting against depression especially in old age. Many research is still going on millets, countless recipes are made by using little millets which is very nutritious for many age groups and that made in different forms and varieties like (samai Pongal, samai briyani, samai kichadi, samai cutlet, samai sweet Pongal) it is reported to enhance little millet in a therapeutic diet.

Following are the health benefits of little millet (Indianmed, 2023):

- Among cereals, samai has been found to have the highest amount of fiber. Its crude fiber content is nearly twice that of other cereals.
- Samai is rich in phenolic compounds that show antioxidant activity.
- This millet is an excellent source of Iron. One serving (30 g) can provide 16% of the daily iron needs for an adult man.
- Like other millets, Samai is also gluten-free. It makes up for the lack of wholegrain fiber in Celiac (gluten-free) diets.
- Samai has a low to medium glycaemic index thus is diabetic friendly.
- It is a rich source of the essential amino acids Histidine, Methionine, and Phenylalanine.

According to Prakash (2023) the following are health benefits of little millet:

- **Rich in potent antioxidants:** A recent research published in the proceedings of the Nutrition Society (2017) mentions that the millet grains are healthy and richer in polyphenol and antioxidant content compared to the millet flour and flakes. Little Millet is also rich in tannins, flavonoids which helps against diseases like diabetes, cardiovascular diseases, cataract, cancer, inflammation, Gastrointestinal problems and delay ageing too
- **Help treat diabetes:** Little millet is known to be a low glycemic index food and also high in dietary fibre. It takes longer time for glucose to enter the bloodstream and hence blood sugar levels remain stable. This effect proves beneficial for diabetics who have to control rapid rise and decline of blood glucose.
- **Helps lower cholesterol:** Little millet is rich in Magnesium which helps improve heart health. It is also rich in Niacin which helps lower cholesterol.
- **Weight loss:** Little millet contains phosphorus which is great for weight loss, tissue repair and energy production after strenuous workout. It also helps detoxify the body. Due to high water-soluble fibre content, they provide satiety, prolonged gastric emptying and weight loss. Hence, little millet is recommended for people with lifestyle disorders like obesity, diabetes and other cardiovascular conditions.
- **Respiratory conditions:** Little millet is known to treat respiratory condition like Asthma.
- **Gluten free**: Samai is gluten free. It is an excellent alternative for those opting for gluten free diet or those with celiac disease/ gluten sensitive enteropathy. Little millets thus, make a perfect addition to the diet of people who do yoga, workouts, cardio, etc. Moreover, its high nutritional value makes it a must-eat in a balanced diet.

The following are health benefits of little millet (Nutritionfact, 2023):

Low glycemic index: Little millet's glycemic index is low. It raises blood sugar slowly due to its low GI. This makes it an excellent choice for diabetics and blood sugar management. Foods with low GI values are digested and absorbed more slowly, providing sustained energy and helping prevent spikes in blood sugar. Little millet's low GI makes it a favourable choice for maintaining stable blood sugar levels.

Dietary fibre: Little millet benefits also include its high dietary fibre content, which promotes digestive health. The fibre in little millet helps maintain regular bowel movements and prevent constipation. Additionally, it supports a healthy gut by providing bulk and aiding in the smooth passage of waste through the digestive system. Including little millet in your diet can contribute to a well-functioning digestive system and reduce the risk of gastrointestinal disorders.

Gluten-free: Another Little millet benefits is that it is naturally gluten-free, making it perfect for those with Celiac disease and gluten sensitivity. Gluten-free diets can safely incorporate Little millet. This grain offers you a nutritional alternative to wheat and other gluten-containing grains, allowing gluten-intolerant people to relish a variety of foods. Unlike wheat, barley, and rye, little millet is naturally gluten-free. Gluten can trigger adverse reactions in those with gluten-related disorders. Little Millet provides a safe and nutritious option for individuals seeking to avoid gluten in their diets. If you have gluten sensitivity or Celiac disease, incorporating a little millet into your diet can offer several benefits. Additionally, it helps alleviate digestive issues commonly associated with gluten consumption. Little Millet's gluten-free nature lets you enjoy a variety of meals without sacrificing taste or nutrients. Dietary fibre aids digestion and reduces constipation. Also, little millet's nutrient-dense composition supports gluten-related patients' health and well-being. By embracing little millet, individuals with gluten sensitivity or Celiac disease can confidently explore new culinary possibilities while ensuring a balanced and gluten-free diet.

Antioxidant properties: Little millet possesses antioxidants that fight harmful free radicals. They protect you against oxidative stress and reduce the risk of chronic diseases. These antioxidants prevent damage to cells and tissues. Little millet may lessen cancer, cardiovascular, and neurological disease risk by lowering oxidative stress.

Good for digestion: Improved digestion is one of its other little millet benefits. Little millet is rich in dietary fibre, promoting healthy digestion and aiding in regular bowel movements. The undigested fibres pass through the body, contributing to a feeling of fullness and assisting in managing blood sugar levels. Little millet can also support detoxification processes in the body and provide a natural energy boost. Fitness enthusiasts often advocate for little millet due to its beneficial properties, and incorporating it regularly into the diet can yield positive results.

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