Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 15, Issue, 08, pp.25589-25610, August, 2023
DOI: https://doi.org/10.24941/ijcr.45819.08.2023

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

REVIEW ARTICLE

ORIGIN, DOMESTICATION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETC DIVERSITY, BREEDING OF RAGI (*Eleusine coracana* L.)

* K.R.M. Swamy

Retd. Principal Scientist & Head, Division of Vegetable Crops, Indian institute of Horticultural Research, Bangalore-560089

ARTICLE INFO

Article History:
Received 19th May, 2023
Received in revised form
15th June, 2023
Accepted 17th July, 2023
Published online 30th August, 2023

Key words:

Ragi, Origin, Domestication, Taxonomy, Botanical Description, Breeding.

**Corresponding Author:*
K.R.M. Swamy

ABSTRACT

Finger millet, also known as *ragi* belongs to the Family: Graminae/ Poaceae, Subfamily: Chloridoideae, Genus: Eleusine and Species: *Eleusine coracana* (L.) Gaertn. Finger Millet is an important millet grown extensively in various regions of India and Africa. It ranks sixth in production after wheat, rice, maize, sorghum and bajra in India. Finger millet is one of the important millets that are mostly consumed by the people in Africa and Asia. It is native to subsistence farmers and poor people in rural parts. The seeds of finger millet have rich nutrients providing energy and nutrients to the rural population. Notably, the calcium content of finger millet is much higher (10-fold) than any other cereal crop. Better resistance to both biotic and abiotic stresses and the long shelf-life of seeds make this crop a crop of the future. Although it received less attention in the first green revolution, rich nutrient profile and climate resilience nature of this crop have attracted the researchers even in Western countries in recent years. Main cultivation areas are parts of eastern and southern Africa – particularly Uganda, Kenya, the Democratic Republic of the Congo, Zimbabwe, Zambia, Malawi, and Tanzania – and parts of India and Nepal. It is also grown in southern Sudan and "as far south" in Africa as Mozambique. In India, ragi is mostly grown and consumed in Rajasthan, Karnataka, Andhra Pradesh, Tamil Nadu, Orissa, Maharashtra, Kumaon region of Uttarakhand and Goa; of which, Maharashtra, Tamil Nadu and Uttarakhand produce the bulk of ragi in the country. There are significant yield variations observed even among the top producing States. In Karnataka, ragi growing areas are concentrated in the southern maidan. Tumakuru district is the leading producer of ragi, followed by Ramnagar, Bengaluru Rural, Hassan, Mandya, Kolar, Chikballapur, Shivamogga, Chikkamagaluru, Chamarajnagar, and Davanagere districts. Finger millet or ragi occupies significant position in India in terms of production and utilization and in entire world. It is one of the most stable food crop. Finger millet is superior to rice and wheat with respect to mineral, fiber and micronutritient contents. Finger millet is a nutrient rich crop. Finger millet is being used as food (grains) in developing countries and as animal feed (straw) in developed countries indicating that it is considered as a poor man's food. Ca is required for a number of basic regulatory functions such as transmission of nerve impulses, contraction and relaxation of muscles, blood coagulation cascade, activation of enzymes, stimulation of hormonal secretion and so on in human body and so on. In the Deccan, ragi is prepared in the form of rotti, bhakri, dosa, idli, porridge, pudding, or a large sphere (mudde) that is broken into pieces that are dipped into sambar. In Sanksrit, the iron-rich ragi is referred to as nrtta-kondaka, meaning dancing grains. Legend holds that Lord Rama, Indra and Hanuman all favoured ragi over rice, on the merits of its immediate and lasting attractiveness. Its merits go beyond looks: it is rich in minerals and unusually for a cereal boasts an amino acid, methionine, that is normally found in significant amounts largely in eggs, meats and fish. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Processing, Uses, Breeding, and Health Benefits of Ragi are discussed.

Citation: ***K.R.M. Swamy*, 2023.** "Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetc Diversity, Breeding, of Ragi (*Eleusine coracana L.*)". *International Journal of Current Research*, 15, (08), 25589-25610.

INTRODUCTION

Finger millet, also known as *ragi* belongs to the Family: Graminae/ Poaceae, Subfamily: Chloridoideae, Genus: Eleusine and Species: *Eleusine coracana* (L.) Gaertn (Mirza and Marla, 2020; Agritech, 2023). Finger Millet, also known as Ragi is an important millet grown extensively in various regions of India and Africa. It ranks sixth in production after wheat, rice, maize, sorghum and bajra in India. The genus *Eleusine* includes eightspecies of diploid and tetraploid annual and perennial herbs. The cultivated species also have several races and subraces and hence, finger millet displays great variability and diversity for most agronomically- important traits. It is a hardy cropwhich can withstand abiotic stress such as water scarcity and cold temperatures. Several genotypes are blast resistant and nutritionally rich especially in minerals and essential amino acids (Mirza and Marla, 2020). Finger millet belongs to genus *Eleusine* in the tribe Eragrostideae family Poaceae (Gramineae), and subfamily Chloridoideae, self pollinating, with chromosome number 2n=36, ranks fourth in importance among millets in the world after sorghum, pearl millet, and foxtail millet (Karki *et al.,* 2020). Finger millet is a minor millet grown in the arid and semiarid tropics and subtropics of Asia and Africa (Mirza and Marla, 2020). It is cultivated for food, as well as fodder and medicinal purposes (Mirza and Marla, 2020). In English ragi is known as Finger Millet, Birdsfoot Millet, African Millet, Coracan Millet, South Indian Millet African Millet, Kurukkan (Rachic and Peter, 1977). The common names in Indian languages are as follows (Vikaspedia, 2020; Vijaykumar, 2021; Valke, 2023; Agritech, 2023):

- Assamese: maruba dhan
- Bengali: marwa
- Gujarati: bavato, nachni, nagali
- Hindi: mandua, mandwa, marua, maruwa, ragi
- Kannada: ragi
- Konkani: nanchani
- Malayalam: ragi
- Marathi: nachani, nagali
- Oriya: mandia
- Punjabi: mandal, mandhul, mundal
- Rajasthani: ragi
- Sanskrit: madhulika, mattakam, nrutyakundala
- Tamil: aariyam, iraki, kel-varaku, keppai
- Telugu: ragi, tamidalu
- Urdu: mandwa, maruwa, ragi

Finger millet or ragi occupies significant position in India in terms of production and utilization and in entire world. It is one of the most stable food crop. Finger millet is superior to rice and wheat with respect to mineral, fiber and micro-nutritient contents (Karki *et al*., 2020). Main cultivation areas are parts of eastern and southern Africa – particularly Uganda, Kenya, the Democratic Republic of the Congo, Zimbabwe, Zambia, Malawi, and Tanzania – and parts of India and Nepal. It is also grown in southern Sudan and "as far south" in Africa as Mozambique (Wikipedia, 2023). In India, ragi is mostly grown and consumed in Rajasthan, Karnataka, Andhra Pradesh, Tamil Nadu, Orissa, Maharashtra, Kumaon region of Uttarakhand and Goa; of which, Maharashtra, Tamil Nadu and Uttarakhand produce the bulk of ragi in the country. There are significant yield variations observed even among the top producing States. Karnataka is the top producer of ragi in India. In Karnataka, ragi growing areas are concentrated in the southern maidan. Tumakuru district is the leading producer of ragi, followed by Ramnagar, Bengaluru Rural, Hassan, Mandya, Kolar, Chikballapur, Shivamogga, Chikkamagaluru, Chamarajnagar, and Davanagere districts. Production (000 tonnes) of finger millet in India during 2022-23 is given in Table 1.

Table 1. Production (000 tonnes) of finger millet in India during 2022-23

State	2022-23
Karnataka	1125.73
Tamil Nadu	180
Uttarakhand	127.11
Maharashtra	79.12
Andhra Pradesh	26.01
Odisha	37.38
Jharkhand	9.79
Gujarat	9.49
West Bengal	1.5
Bihar	2.22
Other states	3.11
Total	1601.46

Finger millet is native to the Ethiopian and Ugandan highlands. Interesting crop characteristics of finger millet are the ability to withstand cultivation at altitudes over 2,000 metres (6,600 ft) above sea level, its high drought tolerance, and the long storage time of the grains (Wikipedia, 2023). Finger millet is widely cultivated in Africa and India, commonly known as 'ragi' found to be originated in the beginning of Iron Age about 5000 years ago in the highlands of Eastern Africa (from western Uganda to Ethiopia) by domestication of wild weedy forms and termed as oldest known. Millets have a special place in the hearts of the Deccan land. Ragi stands out among the millets here. Ragi however, is native to the highlands of East Africa where it has been growing for 5000 years. It arrived in India around 3000 years back, probably coming from trade with the Axumite Empire (Hindavi, 2015).

In the Deccan, ragi is prepared in the form of rotti, bhakri, dosa, idli, porridge, pudding, or a large sphere (mudde) that is broken into pieces that are dipped into sambar (Hindavi, 2015). In Sanksrit, the iron-rich ragi is referred to as nrtta-kondaka, meaning dancing grains. Legend holds that Lord Rama, Indra and Hanuman all favoured ragi over rice, on the merits of its immediate and lasting attractiveness. Its merits go beyond looks:

it is rich in minerals and unusually for a cereal boasts an amino acid, methionine, that is normally found in significant amounts largely in eggs, meats and fish. In flavour, this red millet constitutes a challenge to chocolate, and brings a grainy and glutenous (though it is gluten-free) texture that makes it a wonderfully original comfort meal (Hindavi, 2015). Finger millet has been used across Africa and Southeast Asia for thousands of years. It's used to make bread, beer, and cereal. Today, finger millet can be found in health food stores and large supermarkets throughout the US, and it's widely used as an alternative to wheat or other grains (WebMDEC, 2022). Its utilization in the daily dietary at present is very limited in rural areas only. Processing of finger millet using traditional as well as modern technique for the development of value added and convenient food products will be solution for its promotion and enhancement of consumption will increase profitability. Cake is one of the most popular bakery products (Karki *et al*., 2020). Whole grains are usually ground and sued to make porridges, puddings, cakes and pancakes. A common food for people in Karnataka, Andhra Pradesh and Tamil Nadu is known as 'Mudde or Ragi Sankati. Ragi dosa, ragi roti, ragi balls, biscuits, crispys and bread are common preparations made in Southern states. Grains are soaked and fermented foods are also prepared. Beverages made of malted ragi are popular in South India. Katti is a special dish prepared from ragi powder by Keralities in Idukki and other districts. Husk from finger millet is used in underground storage, as packaging material in pillows and cushions. Ragi straw is a good fodder, plus it is used in preparing beds for animals. It's so versatile in nature that you can prepare idli or dosa batter with it, use the flour to make rotis, koozh and kali for summer. It will cool the body. I was introduced to millets by my Ayurveda doctors for a health condition. With time, I've witnessed drastic changes in my body and fitness level. I am a full-fledged milletarian now and I encourage people to incorporate millets in their everyday diet (Vijaykumar, 2021).

Finger millet is one of the important millets that are mostly consumed by the people in Africa and Asia. It is native to subsistence farmers and poor people in rural parts. The seeds of finger millet have rich nutrients providing energy and nutrients to the rural population. Notably, the calcium content of finger millet is much higher (10-fold) than any other cereal crop. Better resistance to both biotic and abiotic stresses and the long shelf-life of seeds make this crop a crop of the future. Although it received less attention in the first green revolution, rich nutrient profile and climate resilience nature of this crop have attracted the researchers even in Western countries in recent years. Finger millet is a nutrient rich crop. Finger millet is being used as food (grains) in developing countries and as animal feed (straw) in developed countries indicating that it is considered as a poor man's food (Wambi *et al.*, 2020). Ca is required for a number of basic regulatory functions such as transmission of nerve impulses, contraction and relaxation of muscles, blood coagulation cascade, activation of enzymes, stimulation of hormonal secretion and so on in human body and so on (Pravina *et al.*, 2013). Plants are the cheap, convenient and alternative source of dietary Ca. People frequently consume cereal based food products which are low in Ca. Major cereal crops may not provide adequate amount of Ca for low income people. Finger millet contains higher amount of Ca compared to the other major cereals. For example, the Ca content in finger millet (344 mg/100 g) is almost 10-fold higher than wheat (41 mg/100 g), maize (26 mg/100 g) and rice (33 mg/100 g) and three times higher than milk (*Kumar et al*., 2016). So finger millet is an example of Ca rich crop in developing countries of tropical and subtropical regions. Finger millet grains also contain higher content of minerals such as phosphorus, iron and manganese compared to other cereals (Kumar *et al.,* 2016). It has been a valuable health grain in ancient agriculture and yet, since ancient times, Ragi has often been sidelined because of the easy availability of other cereal crops like rice and wheat. Thanks to extensive research and the push to include millets in daily diets to fight malnutrition, Ragi has gained immense popularity in recent times (Vijaykumar, 2021). Being high in protein, calcium, iron and amino acids, ragi is touted as a Superfood. Ragi benefits babies as well, which is why it is one of the most commonly used millets for making porridge for infants (Vijaykumar, 2021).

Crop does not mature uniformly and hence the harvest is to be taken up in two stages. When the ear head on the main shoot and 50% of the ear heads on the crop turn brown, the crop is ready for the first harvest. At the first harvest, all ear heads that have turned brown should be cut. After this drying, threshing and cleaning the grains by winnowing. The second harvest is around seven days after the first. All ear heads, including the green ones, should be cut. The grains should then be cured to obtain maturity by heaping the harvested ear heads in shade for one day without drying, so that the humidity and temperature increase and the grains get cured. After this drying, threshing and cleaning as after the first harvesting (Wikipedia, 2023). Once harvested, the seeds keep extremely well and are seldom attacked by insects or moulds. Finger millet can be kept for up to 10 years when it is unthreshed. Some sources report a storage duration up to 50 years under good storage conditions. The long storage capacity makes finger millet an important crop in risk-avoidance strategies as a famine crop for farming communities (Wikipedia, 2023). Millet is a grain and a staple food in many parts of the world. There are many different kinds of millet, which all have similar health benefits. Finger millet is gaining popularity worldwide because of how easy it is to grow and how adaptable it is as a food (WebMDEC, 2022). In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Processing, Uses, Breeding, and Health Benefits of cocoa are discussed.

ORIGIN AND DOMESTICATION

Finger millet originated in the highlands of Uganda and Ethiopia and domestication began there around 5000 years ago, as evident from the archaeological records of early African agriculture. Finger millet arrived in India probably more than 3000 years ago; India has been debated as its origin for a long time due to the presence of several cultivars in different regions. However, Fuller (2006) did an exhaustive review of the work on the origin of *Eleusine* and confirmed its African origin. Fuller reported that most of the claims of Indian origin of finger millet are widely based on misidentified material ofother species. Finger millet is a fast growing cereal crop that reaches maturity within 3 to 6 months and occasionally in only 45 days. It is generally found in disturbed areas, roadsides and banks. It is commonly found at altitudes between 1000 and 2000 in eastern and southern Africa, and up to 2500-3000 m in the Himalayas. It grows best at an average temperature of 23°C but can withstand cooler and hotter conditions. An annual rainfall ranging from 500 to 1000 mm is suitable, provided it is well distributed across the growing season. Finger millet will keep growing in drier conditions, but pearl millet and sorghum will be preferred below 750 mm. Finger millet is intolerant of flooded conditions but withstands some waterlogging. It does not do well in areas of heavy rains, but prefers damp conditions. Finger millet is adapted to a wide range of soil conditions though it prefers fertile, well-drained sandy to sandy loam soils with a pH ranging from 5 to 7. However, it will grow in lateritic or black heavy vertisols and has some tolerance to alkaline and moderately saline soils (Heuzé and Tran, 2015).

Eleusine *coracana* (L.) Gaertn. subsp. *coracana* (Finger millet or *Eleusine*) is widely cultivated in Africa and India, commonly known as 'ragi' found to be originated in the beginning of Iron Age about 5000 years ago in the highlands of Eastern Africa (from western Uganda to Ethiopia) by domestication of wild weedy forms and termed as oldest known domesticated tropical African cereal. Archaeological records of finger millet are less and not authenticated although distribution, linguistic and historical evidences seem to suggest an African rather than Indian origin of finger millet. From eastern Africa, it spread to elsewhere; to India about 3000 years ago, to southern Africa about 800 years ago, before spreading to South-East Asia. It is widespread in warm temperate regions from Africa to Japan and Australia. Finger millet varieties grown in southern India and African lowlands are morphologically indistinguishable. There are also findings that finger millet was domesticated about

5000 years ago in eastern Africa (possibly Ethiopia) which later on introduced into India, about 3000 years ago. The closest wild relative of finger millet is *E. coracana* subsp. *africana* which is native of Africa. As a cultivated crop, it is at present most important in eastern and southern Africa as well as in the Indian sub-continent, and is occasionally cultivated elsewhere in the tropics. In South-East Asia, it is grown on a small scale thereby not attaining commercial importance. Morphological study supplemented with cytogenetical observations and distribution suggested that *E. coracana* subsp. *africana* is a wild finger millet. This subspecies of *Eleusine* is widely spread along the highlands of East Africa. Consequently, it was concluded that finger millet originated in the East African highlands and was subsequently introduced and domesticated in India. The species *E. coracana* subsp. *coracana* includes all cultivated finger millets, on the basis of inflorescence shape and its correlation with geographic distribution. Evidences of the patterns of variability in African and Asian finger millets has by large indicated comparatively larger diversity in African germplasm rather than to Indian collections, supporting to the view that Africa could be the primary centre of origin. The long history of cultivation of finger millet in the Indian sub-continent accompanied by natural mutations and human selection has resulted in the generation of large diversity in landraces and local cultivars in India. Detailed study of various characters in Indian germplasm has resulted that for economically important characters such as finger length, finger width, finger number, grain yield, ear weight, total biomass and leaf number, the Indian germplasm possesses large variability indicating India as the secondary centre of diversity (Joshi *et al.*, 2021). Finger millet originated in East Africa (Ethiopian and Ugandan highlands). It was claimed to have been found in an Indian archaeological site dated to 1800 BCE (Late Bronze Age); however, this was subsequently demonstrated to be incorrectly identified cleaned grains of hulled millets. The oldest record of finger millet comes from an archaeological site in Africa dating to the 8th century AD (Wikipedia, 2023). Ragi is mentioned in India by the ancient Sanskrit writers who refer to it as 'Rajika'. It is suggested that *Eleusine coracana* is a cultigens of the wild species *Eleusine indica (*L.) Gaertn, domesticated by the early man in India. DeCandolle (1886) to consider that *Eleusine coracana* originated in India, from where it spread to Arabia and Africa, nearly 3,000 years ago. Considering its predominant cultivation in Southern India, this region is accepted to be the primary centre of its origin. *Eleusine indica* is considered to be the immediate ancestor of the cultivated form *Eleusine coracana* (Isha, 2023). Finger millet originated in Africa and has been cultivated for many thousands of years in Uganda and Ethiopia. In India, the crop was probably introduced 4000 years ago, and has been found in archeological excavations in the Harappan Civilization (Isha, 2023). The cultivated species of *E.coracana* arose as an allotetraploid from its wild relative *E.indica*. Asia and Africa are supposed to be place of origin. The African types are having bolder grain (Eagri, 2023). Ragi is native to Angola, Burkina, Burundi, Cameroon, Central African Repu, Chad, Ethiopia, Nigeria, Rwanda, Socotra, Sudan, Zaïre (POWO, 2023). Ragi is distributed into Afghanistan, Andaman Is., Assam, Bangladesh, Brazil West-Central, China North-Central, China South-Central, China Southeast, Czechoslovakia, East Himalaya, Egypt, Fiji, Gulf States, Hainan, India, Inner Mongolia, Japan, Jawa, Laos, Lesser Sunda Is., Libya, Malaya, Maldives, Mali, Maluku, Marianas, Mauritius, Mexico Northeast, Mexico Northwest, Mexico Southwest, Myanmar, Nepal, Nicobar Is., Oman, Pakistan, Philippines, Réunion, Saudi Arabia, Senegal, South Carolina, Sri Lanka, Sulawesi, Sumatera, Taiwan, Tanzania, Thailand, Transcaucasus, Trinidad-Tobago, Tunisia, Vietnam, West Himalaya, Western Australia, Yemen **(Fig. 1)** (POWO, 2023).

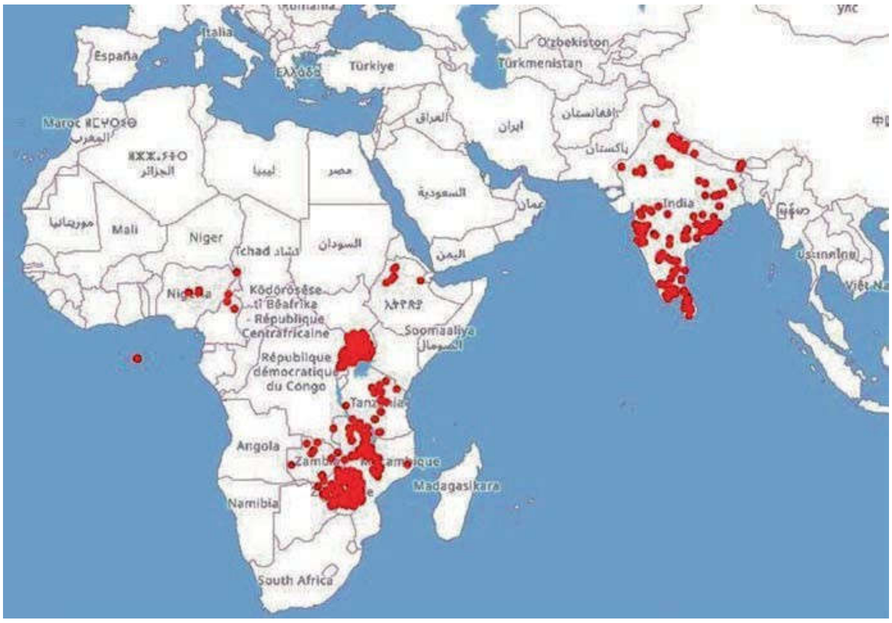


Fig. 1: Distribution of *Eleusine* accessions map

TAXONOMY

Finger millet, also known as *ragi* belongs to the Family: Graminae/ Poaceae, Subfamily: Chloridoideae, Genus: Eleusine and Species: *Eleusine coracana* (L.) Gaertn (Heuzé and Tran, 2015; Mirza and Marla, 2020; Agritech, 2023; Wikipedia, 2023). Finger Millet, also known as Ragi is an important millet grown extensively in various regions of India and Africa. Its scientific name is Eleusine coracana. It ranks sixth in production after wheat, rice, maize, sorghum and bajra in India. The genus *Eleusine* includes eight species of diploid and tetraploid annual and perennial herbs. The cultivated species also have several races and subraces and hence, finger millet displays great variability and diversity for most agronomically- important traits. It is a hardy crop which can withstand abiotic stress such as water scarcity and cold temperatures. Several genotypes are blast resistant and nutritionally rich especially in minerals and essential amino acids (Mirza and Marla, 2020).

The genus *Eleusine* includes nine annual and perennial species as recognized with eight African species and one New World species (*E. tristachya* Lam.) native to Argentina and Uruguay (Lovisolo and Galati 2007). The species of *Eleusine* Gaertn. are distributed in the tropical and subtropical areas (Fig. 3.1) of India, Myanmar, Sri Lanka, Nepal, China and Japan in Asia; while in Africa, it is grown in Uganda, Kenya, Tanzania, Ethiopia, Eritrea, Rwanda, Zaire and Somalia (Upadhyaya et al. 2010). It is an annual allotetraploid (2n = 4X = 36, AABB) that includes two distinct subspecies: *E. coracana* ssp. *coracana* (L.) Gaertn. and *E. coracana* ssp. *Africana*. *Coracana* is the cultivated ssp. while *africana* is the wild ssp. Wild finger millet is native to Africa and is believed to have migrated from there to Asia and the Americas. The cultivated ssp. *coracana* was domesticated from wild populations of *E. coracana* ssp. *africana* as suggested by morphological and cytogenetic evidence, and through molecular studies. (Hilu and Johnson 1992). Finger millet has a cultivated form (*Eleusine coracana* subsp. *coracana*) and a wild form (*Eleusine coracana* subsp. *africana*) that is an aggressive colonizer (Heuzé and Tran, 2015).

There are ten species under the genus *Eleusine* Gaertn, seven diploid (2n=16, 18 and 20) and three tetraploid taxa (2n=36 or 38). *Eleusine africana* (Kenn.-O'Bryne), *Eleusine coracana* (L.) Gaertn, *Eleusine floccifolia* (Spreng), *Eleusine indica* (L.) Gaertn, *Eleusine intermedia* (Chiov.) (S.M.Phillips), *Eleusine jaegeri* (Pilg.), *Eleusine kigeziensis* (S.M.Phillips), *Eleusine multiflora* (Hochst. ex A.Rich), *Eleusine semisterilis* (S.M.Phillips) and *Eleusine tristachya* (Lam.) Lam. Different studies confirmed that *Eleusine coracana* has originated from *E. indica* and *E. floccifolia* genomes and selected for cultivation from its wild type *E. Africana* (Wikipedia, 2023).

Finger millet belongs to genus *Eleusine* in the tribe Eragrostideae family Poaceae (Gramineae), and subfamily Chloridoideae, self pollinating, with chromosome number 2n=36, ranks fourth in importance among millets in the world after sorghum, pearl millet, and foxtail millet (Karki *et al*., 2020). Finger millet is a minor millet grown inthe arid and semiarid tropics and subtropics of Asia and Africa (Mirza and Marla**,** 2020). It is cultivated for food, as well as fodder and medicinal purposes (Mirza and Marla**,** 2020). In English ragi is known as Finger Millet, Birdsfoot Millet, African Millet, Coracan Millet, South Indian Millet African Millet, Kurukkan (Rachic and Peter, 1977).

Finger millet (*Eleusine coracana* (L.) Gaertn. subsp. *coracana*) is cultivated in eastern and southern Africa and in southern Asia. The closest wild relative of finger millet is *E. coracana* subsp. *africana* (Kennedy-O'Byrne) Hilu & de Wet. Wild finger millet (subsp. *africana*) is native to Africa but was introduced as a weed to the warmer parts of Asia and America. Derivatives of hybrids between subsp. *coracana* and subsp. *africana* are companion weeds of the crop in Africa. Cultivated finger millets are divided into five races on the basis of inflorescence morphology. Race *coracana* is widely distributed across the range of finger millet cultivation. It is present in the archaeological record of early African agriculture that may date back 5,000 years. Racial evolution took place in Africa. Races *vulgaris, elongata, plana*, and *compacta* evolved from race *coracana*, and were introduced into India some 3,000 years ago. Little independent racial evolution took place in India **(Fig. 2)** (de Wet *et al*., 1984).

Fig. 2. Races and subraces of the species *Eleusine coracana*

Wild types: (Rachic and Peter, 1977).

- ***Eleusine indica*:** 2n = 18 chromosomes; it has a smaller plant; narrow rachis; thin stems, relatively short glumes and lemma, and spikelets; shattering spikelets, small seeds are enclosed in glumes and thin racemes.
- ***E. africana*:** 2n = 36 chromosomes; it has a larger plant but generally similar to *E. indica*; has wider rachis, thicker stems and longer spikelets, glumes, and lemmas; the spikelets shatter and it has shattering seeds as well.

Cultivated types: (Rachic and Peter, 1977).

- ***E. coracana* (African-highland type):** 2n - 36 chromosomes; longer lemmas, glumes, and spikelets; spikelets are non-shattering and it has plump grains; the seeds are enclosed inside the glumes.
- ***E. coracana* (Afro-Asiatic type):** 2n — 36 chromosomes; it has shorter glumes, lemmas and spikelets; has non-shattering spikelets and plump seed; and seeds thresh free from the glumes.

Wild relatives (Eagri, 2023):

The genus Elevsine comprises of 11 species of which 6 are diploids and 5 are tetraploids.

(2n = 18)

1. *Eleusine indica*
2. *Eleusine oligostachya*
3. *E.tristachya*
4. *E. poranansis*
5. *E. jaegeri*
6. *E. flacifolia*

(2n = 36)

1. *Eleusine coracana*
2. *E. africana*
3. *E. longipoides*
4. *E. verticillata*
5. *E. cagopoides*

Synonyms (Heuzé and Tran, 2015)

1) *Cynosurus coracanus* L.,
2) *Eleusine africana* Kenn.-O'Byrne,
3) *Eleusine indica* subsp. *africana* (Kenn.-O'Byrne) S. M. Phillips,
4) *Eleusine tocussa* Fresen.

Synonyms (Wikipedia, 2023)

1) *Cynodon coracanus* Raspail
2) *Cynosurus coracanus* L.
3) *Eleusine cerealis* Salisb. nom. illeg.
4) *Eleusine dagussa* Schimp.
5) *Eleusine luco* Welw. nom. inval.
6) *Eleusine ovalis* Ehrenb. ex Sweet nom. inval.
7) *Eleusine pilosa* Gilli
8) *Eleusine reniformis* Divak.
9) *Eleusine sphaerosperma* Stokes nom. illeg.
10) *Eleusine stricta* Roxb.
11) *Eleusine tocussa* Fresen.

Synonyms (Indiabiodiversity, 2023)

Cynodon coracanus Raspail
Cynosurus coracanus L.
Eleusine cerealis Salisb., nom. superfl.
Eleusine coracana var. *stricta* (Roxb.) Nees
Eleusine coracana var. *tocussa* (Fresen.) Franch.
Eleusine dagussa Schimp.
Eleusine indica var. *coracana* (L.) Fiori
Eleusine indica var. *stricta* (Roxb.) Chiov.
Eleusine luco Welw., nom. nud.
Eleusine ovalis Ehrenb. ex Sweet, nom. nud.
Eleusine pilosa Gilli
Eleusine reniformis Divak.
Eleusine rigida Spreng.
Eleusine sphaerosperma Stokes, nom. superfl.
Eleusine stricta Roxb.
Eleusine tocussa Fresen.
Eleusine tocussa var. *erytroleuca* Chiov.
Eleusine tocussa var. *erytromelana* Chiov.
Eleusine tocussa var. *flavocarpa* Chiov.
Eleusine tocussa var. *leucocarpa* Chiov.
Eleusine tocussa var. *melanocarpa* Chiov.
Eleusine tocussa var. *olivacea* Chiov.

Synonyms (POWO, 2023).

Homotypic Synonyms

1. Cynosurus coracanus L. in Syst. Nat., ed. 10. 2: 875 (1759) (Do not give space)
2. *Eleusine cerealis* Salisb. in Prodr. Stirp. Chap. Allerton: 19 (1796), nom. superfl.
3. *Eleusine indica* var. *coracana* (L.) Fiori in Nuov. Fl. Italia 1: 114 (1923)
4. *Eleusine indica* subsp. *coracana* (L.) Lye in Lidia 4: 150 (1999)
5. *Eleusine sphaerosperma* Stokes in Bot. Mat. Med. 1: 149 (1812), nom. superfl.

Heterotypic Synonyms

1) *Cynodon coracanus* Raspail in Ann. Sci. Nat. (Paris) 5: 303 (1825)
2) *Eleusine coracana* var. *stricta* (Roxb.) Nees in Fl. Afr. Austral. Ill.: 251 (1841)

3) *Eleusine coracana* var. *tocussa* (Fresen.) Franch. in Bull. Soc. Hist. Nat. Autun 8: 377 (1895)
4) *Eleusine dagussa* Schimp. in Gartenflora 21: 205 (1872)
5) *Eleusine indica* var. *stricta* (Roxb.) Chiov. in Nuovo Giorn. Bot. Ital., n.s., 26: 83 (1919)
6) *Eleusine luco* Welw. in Apont.: 591 (1858 publ. 1859), nom. nud.
7) *Eleusine ovalis* Ehrenb. ex Sweet in Hort. Brit., ed. 2: 571 (1830), nom. nud.
8) *Eleusine pilosa* Gilli in Ann. Naturhist. Mus. Wien 69: 50 (1965)
9) *Eleusine reniformis* Divak. in Madras Agric. J. 46: 486 (1959)
10) *Eleusine rigida* Spreng. in Syst. Veg., ed. 16. 4(2): 36 (1827)
11) *Eleusine stricta* Roxb. in Fl. Ind. 1: 344 (1820)
12) *Eleusine tocussa* Fresen. in Mus. Senckenberg. 2: 141 (1837)
13) *Eleusine tocussa* var. *erytroleuca* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)
14) *Eleusine tocussa* var. *erytromelana* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)
15) *Eleusine tocussa* var. *flavocarpa* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)
16) *Eleusine tocussa* var. *leucocarpa* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)
17) *Eleusine tocussa* var. *melanocarpa* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)
18) *Eleusine tocussa* var. *olivacea* Chiov. in Monogr. Rapp. Colon. 19: 55 (1912)

BOTANICAL DESCRIPTION

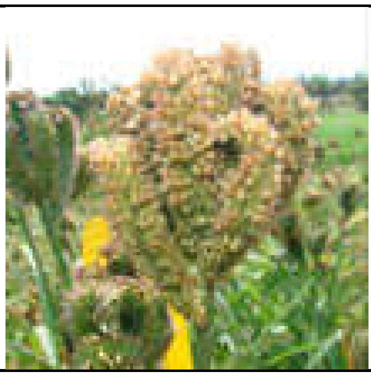
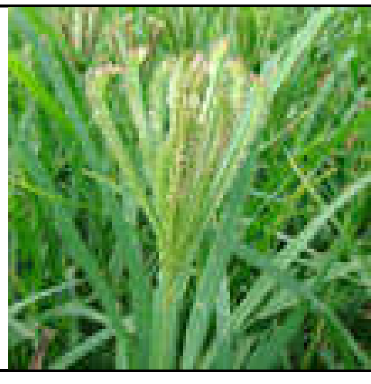
Stems of ragi are erect or slightly kneed, compressed and glabrous. The leaves are numerous distichous; the sheaths compressed, open, striate, glabrous, and with more or less ciliate margins; the ligules are short membranous and fimbriate; the blades are linear and tapering to an acute point, folded and striate. glabrous except at the often ciliate margins. The inflorescence is a terminal umbel of 2- 10 straight thick sessile spikes 3- 5 in. long, usually with 1 to 2 (rarely more) additional spikes 1/4 to 3 in. below each rachis, is angular, pubescent villous at the base, but glabrous above. The spikelets are often curved, crowded, 2 -10 flowered. The lower glume is ovate, obtuse and keeled with lateral nerve close to the keel. The upper glume is similar, but slightly longer. All flowers arc perfect except the terminal which may be only seminate or infertile. The lemmas are broadly ovale, acute and three-nerved. The paleas are somewhat shorter than the lemmas, two-keeled with the keel wings. There are two lodicules, broad and trunky; three stamens; an obovate ovary with distinct style and plumose stigma. The grain is oblong, reddish brown with finely curved striate, and falls at maturity (Rachic and Peter, 1977).

Finger millet is a cereal grass grown mostly for its grain (for information concerning the forage uses of finger millet, see the Finger millet, forage datasheet). Finger millet is a robust, tufted, tillering annual grass, up to 170 cm high. The inflorescence is a panicle with 4-19 finger-like spikes that resembles a fist when mature, hence the name finger millet. The spikes bear up to 70 alternate spikelets, carrying 4 to 7 small seeds. The seed pericarp is independent from the kernel and can be easily removed from the seed coat. Finger millet is a staple food in many African and South Asian countries. It is also considered a helpful famine crop as it is easily stored for lean years. The grain is readily digestible, highly nutritious and versatile, and can be cooked like rice, ground to make porridge or flour, or used to make cakes. Sprouted grains are recommended for infants and elderly people. Finger millet is also used to make liquor ("arake" or "areki" in Ethiopia) and beer, which yields by-products used for livestock feeding (Heuzé and Tran, 2015).

Ragi is having shallow, branched fibrous root system. As the seedlings begin to grow, fibrous roots arise from the basal nodes. When seedlings are pulled out, most of the roots get torn off but very soon fresh roots develop. Stem: The stem is slender, erect, glaborous and smooth, sometimes branching. It is compressed, elliptic and it is green in colour. It is hollow at the internodes and solid at the nodes. The lower internodes are short and the longest being the terminal node carrying the inflorescence. The plant is robust, free tillering. Tufted annual grass up to 170 cm tall. Leaf: The leaves are arranged alternately on either side of the compressed elliptical culm and it is green in colour. The leaves are distichous, simple and entire. The leaf sheath envelops the stem more or less completely and very little of internodes are exposed. The leaf sheath is flattened, over lapping, split along the entire length. The leaf blade has a prominent midrib, ligule, a fringe of hairs. Leaf blade is linear and taper to an acute point, folded and striated and often with ciliated margins. Ligule is 1 to 2 mm long, fimbriate. Panicle: It is borne on a long peduncle. The panicle consists of a variable number of spikes ranging from 3 to 20 arranged in a bird's foot style. It resembles fingers on hand; hence its common name is finger millet. The rachis of the spikes is flat. There are four types of panicle shapes, namely, (i) In-curved (short fingers), (ii) Top-curved (longer fingers), (iii) Open (longest fingers) and (iv) Fisty (so long that it bends and take a shape like fist). Spikelet: The spikelets are carried on small rachillae at the ends of the branches of the panicle. They are often curved, crowded, 2 to 4 flowered. They are ovoid-ellipsoid, up to 10 mm. They are sessile and arranged in 2 rows alternately attached to one side of the rachis. Spikelets about 70 arranged alternately on rachis, each containing 4 to 7 seeds. Each spikelet is 3 to 7 flowered enclosed by the lemma and palea. The lower glume is ovate, obtuse and keeled with lateral nerve close to the keel. The upper glume is similar, but slightly longer. Enclose bisexual flowers, but terminal ones sometimes sterile or male, arranged in two opposite rows and two lodicules each. Flowering lemmas are broadly ovule, acute, three nerved and 2-5 mm long. Palea slightly shorter than lemma, two keeled with the keel wings. There are two lodicules broad and trunky . Grain: The grain is globose and smooth one with the pericarp thin, hyaline and loose. The base of the grain is slightly flattened with a small depression called as hilum. The grain shows a slight flattening, which marks the position of the embryo. The naked grain is more or less spherical in shape and the colour can be brown, reddish brown, black, orange red, purple and white (Das, 2020).

It is an annual herbaceous cereal crop, growing to a height of 30-150 cm and maturation starts in 75-160 days. Leaves are narrow, grass-like and produce many tillers and nodal branches. The panicle consists of a group of digitally arranged spikes referred to as a finger. The inflorescence is a panicle with 4-19 finger-like spikes that takes after a clench hand when developed, consequently the name finger millet. The seed pericarp is autonomous from the part and can be handily expelled from the seed coat. The pericarp is thin and papery. Its outer layer comprises isodiametric cell with wavy walls. The inner layer is less robust with deep coloured. Aleuronic cells are small and single layer. Endosperm is generally friable. The tannins are present in testa. The grains are round and oval in shape and light brown to reddish brown or dark brown colour. A wide range of grain colors (dark brown, light brown, ragi brown, reddish brown and white) were observed in finger millet germplasm collection introduced from Southern and Eastern Africa. Majority of the accessions were light brown (57.2%), followed by reddish brown (22.3%), dark brown (10.2%), ragi brown (8.4%) and white (1.9%) (Karki *et al.*, 2020).

Ragi is having fibrous root system. It is shallow, branched, rooting at lower nodes. As the ragi grain germinates, the radical pierces its way out and forms the seminal root. Lateral roots are formed from the seminal root. As the seedlings begin to grow, fibrous roots arise from the basal nodes. When seedlings are pulled out, most of the roots get torn off but very soon fresh roots develop. Stem is slender, erect, compressed, glaborous and smooth, sometimes branching. The stem is compressed, elliptic and it is green in colour. The plant is robust, free tillering, tufted annual grass up to 170 cm tall. The stem is hollow at the internodes and solid at the nodes. The lower internodes are short and the longest being the terminal node carrying the inflorescence. The plant has a packing of a large number of leaves on short slender culms. The leaves are arranged alternately on either side of the compressed elliptical culm and it is green in colour. The leaves are distichous, simple and entire. The leaf sheath envelops the stem lore or less completely and very little of internodes are exposed. The leaf sheath is flattened, over lapping, split along the entire length. The leaf blade has a prominent midrib, ligule, a fringe of hairs. Leaf blade is linear and taper to an acute point, folded and striated and often with ciliated margins. Ligule is 1 to 2 mm long, fimbriate. Many of the well grown leaves have a tendency to snap and bend down about their upper middle and called as bent leaves. The internodes of the culm are not of equal length. At the base of the stem, the nodes are often crowded are referred as 'conjested nodes'. Two to four nodes get conjested together in the culms. Inflorescence or Panicle is borne at the end of the vegetative shoot. It is branched with one or a few branches below the main cluster of 4-19 branches. It is borne on a long peduncle. The panicle consists of a variable number of spikes ranging from 3 to 20 arranged in a bird's foot style. It resembles fingers on hand, hence its common name is finger millet and with an odd one a little lower down the whorl and called the thumb. The rachis of the spikes is flat. The branches are slender to robust, linear to oblong, up to 24 cm long, each branch with 60-80 spikelets. There are four types of panicle shapes, namely, (i) the top-curved, (ii) the in-curved, (iii) the open and (iv) the fisty. In the in-curved, the fingers are short and curve in and practically close up the central hollowgiving the earhead an obovate shape. In the top-curved, the curved fingers are longer with the result that they retain the central hollow. In the open, the fingers are the longest and gape out and present a characteristic funnel-shaped appearance. The fisty has the in-curved spikelets in a greater intensity of curving giving a roundish, fist-like appearance. The spikelets are carried on small rachillae at the ends of the branches of the panicle. They are often curved, crowded, 2 to 4 flowered. They are ovoid-ellipsoid, up to 10 mm. They are sessile and arranged in 2 rows alternately attached to one side of the rachis. Spikelets about 70 arranged alternately on rachis, each containing 4 to 7 seeds. Each spikelet is 3 to 7 flowered enclosed by the lemma and palea. The lower glume is ovate, obtuse and keeled with lateral nerve close to the keel. The upper glume is similar, but slightly longer. The lower 2 glumes are 1-4 mm long with 5-7 veined keels and it is barren. Enclose bisexual flowers, but terminal ones sometimes sterile or male, arranged in two opposite rows and two lodicules each. Flowering lemmas are broadly oval, acute, three nerved and 2-5 mm long. Palea slightly shorter than lemma, two keeled with the keel wings. There are two lodicules broad and trunky. Stamens three, ovary superior with two dsitinct free styles ending in plumose stigmas. The four types of ear heads, not withstanding their varying finger lengths, do not present very marked differences in the number of spikelets on a finger. The average number of spikelets in a finger had been found to be 67 to 73. In each spikelet, the opening of the florets is from bottom to top and one floret in the spikelet opens per day. An ear head takes seven to eight days to complete its flowering. The grain is globose and smooth one with the pericarp thin, hyaline and loose. The naked grain is more or less spherical in shape and the colour can be brown, reddish brown, black, orange red, purple and white. The base of the grain is slightly flattened with a small depression called as hilum. The grain shows a slight flattening, which marks the position of the embryo. The seed coats are developed from the two integuments of the ovule which are free from each other except at the base. The inner layer has cells which are twice as large as that of the outer layer in the initial stages. The outer layer is thrown into a number of projections, probably as a result of shrinkage of cells and shows numerous more or less concentric configurations as seen in a mature grain (Fig. 3) (Agritech, 2023).

		
Root	**Stems**	**Leaves**
		
Panicle	**Spikelets**	**Spikelets**

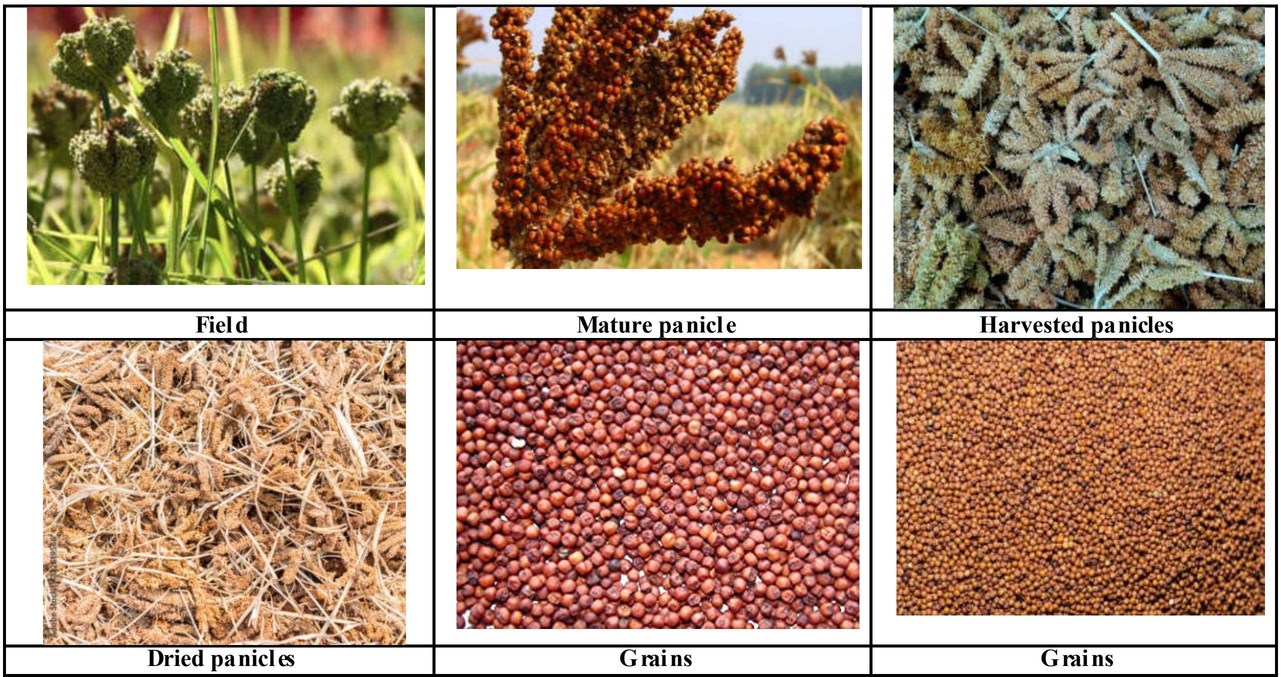


Fig. 3. Botanical Description

Annuals or perennials. Culms erect, 25-60 cm high; nodes glabrous. Leaves linear, 10-80 x 0.3-1 cm, acute or acuminate, rounded or shallowly cordate at base. Sheaths strongly keeled, compressed. Ligules row of hairs. Spikes digitate, 3-8 in number, 2-8 cm long, compact, densely spiculate. Spikelets ovate, 4-6 mm long, 4-6-flowered. Lower glume ovate-oblong, 2-3 x 1.5-3 mm, chartaceous, 3-nerved, keeled, keel scabrid. Upper glume ovate-lanceolate, 3-4 x 1.5-3 mm, chartaceous, 5-nerved, keeled; keel scabrid. Lemmas ovate-acute, 2-4 x 2-3 mm, chartaceous, 3-nerved. Paleas ovate-oblong, 2-3 x 1.5-3 mm, chartaceous, 2-keeled; keels winged, scabrid. Stamens 3; anthers 1-1.5 mm long. Grain orbicular or globose, dark-brown, exposed (Indiabiodiversity, 2023).

Floral Biology: The inflorescence of ragi is a terminal whorl bearing 2 to 10, but averaging 5 or 6 spikes arranged like a bird's foot at the top of the peduncle. The lowest spike is separated by 2 to 5 cm from the other spikes and which arise from the same point at the end of the stem. This lower spike appears to be a thumb or a bird's first claw; it is commonly referred to as the thumb, and the other spikes as the fingers. In each finger there are about 70 spikelets, each spikelet having five to seven complete flowers. In the spikelet the flowering proceeds from bottom to top and in a finger the order of flowering is from the top spikelet downward. An earhead contains 1,500 to 3,000 flowers, and the flowering period varies from six or seven to ten days, the largest number opening on the third day after flowering commences. Anthesis and pollination in *E. coracana* has been studied and described by several authors. The complete emergence of the inflorescence requires about 10 days and flowering extends over at least 7 or 8 days. Ragi types with curved panicles undergo anthesis between 2 and 5 a.m., while panicles with open spikes tend to flower between 1 and 3 a.m. The general tendency of the flowers is to open and progress from the top to the bottom in a finger. In a spikelet, however, the order is reversed and proceeds from the bottom to the top, and from the bigger to the smaller flower. The stigma remains receptive for a very short period after its emergence from the glumes. The period of anthesis in the flower is very short and is conducive to self-pollination, but occasionally cross-pollination occurs. Flowering to be at its maximum at 8 a.m. when the humidity is at its highest, between 95 and 99%, and when the minimum and maximum temperatures are 70 to 74 F and 76 to 87° F, respectively. Flowering continued there up until 10 a.m. and the anthers were found to be dehiscing and shed their pollen about 45 min after first emerging. They observed blooming to synchronize on all the fingers of an car and found the major portion of the blooming is completed within two or three days. Ragi pollen was germinated artificially on moist filler paper under glass. Large quantities of pollen were obtained when ragi flowers with several peduncles were immersed in water and kept overnight. Ample pollen was obtained the next day in the morning between 7 and 9 a.m. when the anthers were kept moist, but they readily burst when allowed to dry. They found that rainy days, early mornings, with heavy dews or artificially maintained high humidity effectively prevented pollen dehiscence. The flower of ragi is very small and extremely difficult to manipulate; in fact, some form of magnification is essential in order to emasculate the tiny floret. The fact that anther dehiscence is prevented by high humidity offers a possible alternative to the conventional method of emasculation followed by pollination or use of the hot water method, which is probably more commonly used. This would involve maintaining a high humidity in the immediate vicinity of the florets by keeping a moist chamber around the plant or by bagging the head in a light wet wrapper covered with a plastic bag. 17 These high humidity conditions could be maintained until all the heads had exerted their anthers and these could be wiped off' with a solution of water and possibly a detergent following which the desired pollen could be introduced for fertilization purposes **(Fig.4)** (Rachic and Peter, 1977).

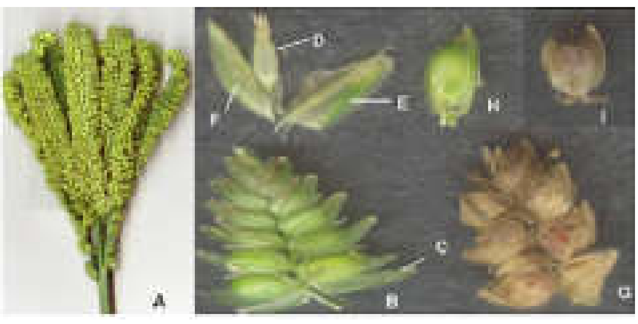


Fig. 4. Inflorescence and spikelet of finger millet. (A) Inflorescence; (B) Spikelet of finger millet; (C) Outer glume; (D) Ovary; (E) Lemma; (F) Palea; (G) Matured spikelet; (H) Grain with in lemma and palea; (I) Matured grain with in lemma and palea.

The variability in floral structure and floral biology was studied in 24 strains of finger millet. The inflorescence consisted of a cluster of variable number of spikes called fingers. Each finger has two opposite rows of spikelets. A spikelet contains variable number of florets. The florets are hermaphrodite, perfect except for the terminal florets. The floret is covered by two large glumes, enclosed between a pair of palea. The florets are in the axil of lemma. The androecium consists of three stamens. The gynoecium is bicarpellary, unilocular with superior ovary. Near the base of ovary two lodicules are present. There was a wide range of variation in the length of anther, filament, stigma and style. Anthesis occurred between 1.00 a.m. to 6.00 a.m., the peak period of anthesis being between 3.00 to 5.00 a.m. The pollen viability at the time of dehiscence of anthers ranged from 76.92 to 100 per cent. The pollen remained viable for 20 minutes (Dodake and Dhonukshe, 1998).

Finger millet inflorescence is in the whorl of 2-11 digitate, straight or slightly curved spikes. The spike is 8-15 cm long and 1.3 cm broad. In each spike, about 50-70 spikelets are arranged alternatively on one side of the rachis. Each spikelet contains 3-13 florets. The florets are covered by two large barren leaves each being enclosed between a pair of scale known as palea. The florets are in the axil of the lower flowering glumes known as lemma, which has small appendage. Near the base of the ovary, two little scaly lodicules are present. The three stamens having anther 0.5-0.8 mm long, not penicillate. The gynoecium is bi-carpellary, uni-locular with superior ovary having two styles with plumose stigma. The androecium almost surrounds the stigma, which ensured self pollination. The filament is very short (0.48-0.85 mm), while anthers are bigger than filaments. The feathery branched stigma is of 0.83 mm in length. The seed is small (1.2-1.8 mm in diameter) and light brown to brick red in colour. However, white grained finger millet genotypes are also developed by various research institutes in India (Gupta *et al*., 2011).

Anthesis and pollination: The study revealed that when stigma comes out of the lemma, it is covered with a thick cloud of pollen dust due to association of elongation of style and filaments with anthers bursting. This condition hardly allows any chance for cross pollination. The anthers get dehisced while still being inside the palea. Soon after the dehiscence of anthers, the flower is observed to be closed with no traces of stigma. Only empty dehisced anthers are observed hanging out from the closed flowers at low humidity and high temperature. At high humidity and low temperature both anthers and stigma are observed hanging outside from the closed flowers. This behavioural sequence predisposes finger millet into cleistogamous as well as chasmogamous species. Within a spike, spikelet opens from the top to downward while within a spikelet floret opens from bottom to top and one floret in a spikelet opens per day. The maximum number of flowers opens on the third day after initiation of flowering. It takes 5-7 days to complete flowering. The anthesis occurs between 1.00 to 5.00 a.m. As soon as lemma and palea begins to gap, the stigma and anthers emerge almost concurrently. The anthers dehiscence longitudinally and it occurs prior to the opening of the florets. The sticky stigma and anthers attained the same height inside the flower at the time of dehiscence. The anthers dehisce and pollinate their own stigmas. The pollen remains viable for 20 min while receptivity of stigma is up to 5 h. Estimation of natural crossing does not exceed 1% in finger millet. Inter-varietal hybridization using contact method is the simplest and easiest way. For the successful hybridization, genotypes having dominant character such as pigmentation on nodes have been used as male parent which helps in the identification of true hybrids in the F1 generation (Gupta *et al*., 2011).

GENETICS AND CYTOGETICS

Finger millet (Eleusine *coracana* (L.) Gaertn.) is an allotetraploid evolved from its wild progenitor, *E. coracana* subsp. *africana*. The genus *Eleusine* contains about 10 species, both annuals and perennials, with three basic chromosome numbers 8, 9, and 10. Four are tetraploids, namely, *E. coracana* (2n = 4x = 36, AABB), *Eleusine africana* (2n = 4x = 36, AABB) and *Eleusine kigeziensis* (2n = 4x = 36, AADD), and *Eleusine reniformis* (2n = 4x = 36); Seven are diploids with a basic chromosome number of 8 in *Eleusine multiflora* (2n = 2x = 16, CC), 9 in Eleusine indica (2n = 2x = 18, AA), *Eleusine* tristachya (2n = 18, AA), *Eleusine floccifolia* (2n = 18, BB), *Eleusine intermedia* (2n = 18, AB), and *Eleusine verticillata* (2n = 2x = 18), and 10 in *Eleusine jaegeri* (2n = 2x = 20, DD). *E. coracana* subsp**.** *africana* is considered as a putative progenitor to cultivated finger millet, *E. coracana* subsp**.** *coracana*, and are completely cross-compatible and produce fertile hybrids. Domestication of cultivated finger millet, *E. coracana* started around 5000 years ago in Western Uganda and the Ethiopian highlands and the crop extended to the Western Ghats of India around 3000 BC. Cytologic analyses of hybrids, chloroplast DNA restriction analysis, and *in situ* hybridization of diploid and polyploidy species shows that *E. indica* is the "A" genome donor, while *E. floccifolia* is the "B" genome donor of cultivated *E. coracana* (Vetriventhan *et al*., 2016).

Scientists of UAS Bengaluru achieved the sequencing of the ragi plant for the first time in the world. Scientists have identified genes which are responsible for drought-tolorance and high nutrient quality of ragi. This information is bound to reduce the time required for developing improved ragi varieties. Ragi plant was first domesticated from a wild species in Western Uganda and Ethiopian highlands before being introduced to India around 3000 BC (Kumar, 2017).

GENETIC DIVERSITY

A world collection of *E.coracana* germplasm was in its entirety was studied in several nurseries under different eco-geographical conditions in India. Typically these varied from Delhi at about 300 in the North and 29 North latitude to the intermediate elevation station, Wellington, Tamil Nadu at about 1,800 m and 12 North latitude. The Indian collections were kept separate by states and their range in variability was studied in this manner. Total variability was quite considerable as indicated by the range in plant height from 16 cm to 145 cm, in basal tillering from 1 to 32, in number of ears per plant from 1 to 70, in number of digits per main ear from 2 to 57, in length of the longest finger from 2 to 151 cm, and in weight of main ear from 0.2 to 13.7 g. (Rachic and Peter, 1977).

The grain is oblong, reddish brown with finely curved striate, and falls at maturity (Rachic and Peter, 1977). The naked grain is more or less spherical in shape and the colour can be brown, reddish brown, black, orange red, purple and white (Das, 2020). A wide range of grain colors (dark brown, light brown, ragi brown, reddish brown and white) were observed in finger millet germplasm collection introduced from Southern and Eastern Africa. Majority of the accessions were light brown (57.2%), followed by reddish brown (22.3%), dark brown (10.2%), ragi brown (8.4%) and white (1.9%) (Karki *et al*., 2020). The grain is globose and smooth one with the pericarp thin, hyaline and loose. The naked grain is more or less spherical in shape and the colour can be brown, reddish brown, black, orange red, purple and white (Agritech, 2023). Grain is orbicular or globose, dark-brown, exposed (Indiabiodiversity, 2023). Ragi or finger millet is an important crop used for food, forage, and industrial products. It is distributed in tropical and temperate regions of the world. The germplasm identification and characterization is an important link between the conservation and utilization of plant genetic resources. Traditionally, species or varieties identification has relied on morphological characters like growth habit, leaf architecture or floral morphology. Investigation through RAPD (random amplified polymorphic DNA) markers was undertaken for identification and determination of the genetic variation among thirty genotypes of ragi of the family Poaceae. Thirteen selected decamer primers were used for genetic analysis.

Fig. 5. Genetic diversity for seed color, size and shape in ragi

A total of 124 distinct DNA fragments ranging from 300-3000 bp was amplified by using selected random RAPD marker. The genetic similarity was evaluated on the basis of the presence or absence of bands. Cluster analysis was made by the similarity coefficient. It indicated that the 30 genotypes of ragi form two major clusters, first, a major cluster having only one genotype, *i. e.*, Dibyasinha and a second major cluster having twenty-nine genotypes. The second major cluster again subdivides into two minor clusters. A first minor cluster has only three varieties, *i. e.*, Neelachal, OEB-56 and Chilika. The genotypes Neelachal and OEB-56 exhibit a 86% similarity with each other and 80% similarity with Chilika. A second minor cluster has 26 genotypes and is divided into two sub-minor clusters. The first sub-minor cluster has only one genotype (VL-322). The second sub-minor cluster again subdivides into two groups. One group has one genotype and the second group again is divided into two sub-groups, one with 13 genotypes and the other with 11 genotypes. The highest similarity coefficient was detected in a genotype collected from southern India and the least from northern India. The genotypes of finger millet collected from diverse agroclimatic regions of India constitute a wide genetic base. This is helpful in breeding programs and a major input into conservation biology of cereal crop (Das *et al*., 2007).

The material comprised of nineteen white seeded finger millet genotypes and three checks *viz.*, Indaf 11, GPU 26 and GPU 28 grown in randomized block design with three replications. The experiment was carried out at three different locations of Karnataka state viz., Agricultural Research Station (ARS), Hanumana matti; ARS, Devihosur and Main Agricultural Research Station, Dharwad. Observations were recorded on days to 50 per cent flowering, days to maturity, plant height (cm), number of tillers per plant, number of productive tillers per plant, ear head length (cm), finger length (cm), finger number per ear, floret number per spikelet, test weight (g), ear weight per plant (g), straw yield per plant (g) and grain yield per plant (g). The data were recorded on ten random plants per entry in each replication for each environment. High estimate of PCV was recorded for straw yield per plant (22.48%) whereas, moderate estimates of PCV were estimated for traits like number of productive tillers per plant (14.36%), ear head length (10.06%), finger length (12.72%), test weight (15.57%), ear weight per plant (15.14%) and grain yield per plant (16.32%). Days to maturity, days to 50 per cent flowering, plant height, number of tillers per plant, fingers number per ear and florets number per spikelet exhibited low PCV of 6.46, 8.34, 8.73, 9.40, 7.80 and 9.83 per cent, respectively. High estimate of GCV was recorded for straw yield per plant (20.80%). Moderate GCV were recorded for number of productive tillers per plant (13.65%), finger length (12.59%), test weight (14.46%), ear weight per plant (13.73%) and grain yield per plant (14.49%). Whereas, low estimates of GCV were exhibited by characters like days to maturity (6.32%), days to 50 per cent flowering (7.96%), plant height (8.40%), number of tillers per plant (8.67%), ear head length (9.71%), finger number per ear (7.12%) and florets number per spikelet (8.92%). Heritability values for all the characters were found to be high and the values ranged from 78.80 to 98.00 per cent. Finger length recorded the highest heritability values (98.00%) and grain yield per plant recorded the lowest heritability value. Path analysis of yield and yield components revealed that, ear weight per plant and straw yield per plant had highest direct contribution on grain yield per plant. This indicates that, increase in ear weight per plant and straw yield per plant would improve the grain yield (Sonnad *et al*., 2008).

For success in any breeding program and crop improvement effort, it is crucial to understand the amount and distribution of variability present in a gene pool. As finger millet is cultivated under diverse climatic conditions in Asia and Africa, understanding the genetic diversity is vital to identifying genotypes resilient to climate change (Mercer and Perales, 2010). Genotypes tolerant to various biotic and abiotic stresses have more allelic variation compared to susceptible types and thus are very useful for breeding programs. Isozyme and DNA marker analyses have revealed that cultivated finger millet has a narrow genetic base, but variation in the wild subspecies is considerably higher. Considerable diversity is found in finger millet, wherein based on inflorescence morphology they can be grouped into races and subraces. The species *E. coracana* consists of two subspecies, *africana* (wild) and *coracana* (cultivated). The subsp. *africana* has two wild races, *africana* and *spontanea*, while subsp. *coracana* has four cultivated races; *elongata*, ***plana***, *compacta*, and *vulgaris*. These cultivated races are further divided into subraces; *laxa*, *reclusa*, and *sparsa* in race *elongata*; *seriata*, *confundere*, and *grandigluma* in race *plana*; and liliacea, *stellata*, *incurvata*, and *digitata* in race *vulgaris*. The race *compacta* has no subraces (Vetriventhan *et al*., 2016).

Finger millet is one of the most important minor crops, commonly known as 'ragi' and used as a staple food grain in more than 25 countries including Africa and south Asia. Twenty-seven accessions of ragi were collected from different parts of India and were evaluated for morpho-genetic diversity studies. Simple sequence repeat (SSR) and random amplified polymorphic DNA (RAPD) markers were used for assessment of genetic diversity among 27 genotypes of *E. coracana*. High degree of similarity (90%) was obtained between 'IC49979A' and 'IC49974B' genotypes, whereas low level of similarity (9.09%) was found between 'IC204141' and 'IC49985' as evident in morphological and DNA markers. A total of 64 SSR and 301 RAPD amplicons were produced, out of which 87.50% and 77.20% DNA fragments showed polymorphism, respectively. The clustering pattern obtained among the genotypes corresponded well with their morphological and cytological data with a monophyletic origin of this species which was further supported by high bootstrap values and principal component analysis. Cluster analysis showed that ragi accessions were categorised into three distinct groups. Genotypes IC344761, IC340116, IC340127, IC49965 and IC49985 found accession specific in RAPD and SSR markers. The variation among ragi accessions might be used as potential source of germplasm for crop improvement (Prabhu *et al*., 2018).

PROCESSING

Once harvested, the seeds keep extremely well and are seldom attacked by insects or moulds. Finger millet can be kept for up to 10 years when it is unthreshed. Some sources report a storage duration up to 50 years under good storage conditions. The long storage capacity makes finger millet an important crop in risk-avoidance strategies as a famine crop for farming communities (Wikipedia, 2023). As a first step of processing finger millet can be milled to produce flour. However, finger millet is difficult to mill due to the small size of the seeds and because the bran is bound very tightly to the endosperm. Furthermore, the delicate seed can get crushed during the milling. The development of commercial mechanical milling systems for finger millet is challenging. Therefore, the main product of finger millet is whole grain flour. This has disadvantages, such as reduced storage time of the flour due to the high oil content. Furthermore, the industrial use of whole grain finger millet flour is limited. Moistening the millet seeds prior to grinding helps to remove the bran mechanically without causing damage to the rest of the seed. The mini millet mill can also be used to process other grains such as wheat and sorghum (Wikipedia, 2023).

Another method to process the finger millet grain is germinating the seed. This process is also called malting and is very common in the production of brewed beverages such as beer. When finger millet is germinated, enzymes are activated, which transfer starches into other carbohydrates such as sugars. Finger millet has a good malting activity. The malted finger millet can be used as a substrate to produce for example gluten-free beer or easily digestible food for infants (Wikipedia, 2023). Finger millet in its commonly consumed form as a porridge

USES

Finger millet can be ground into a flour and cooked into cakes, puddings or porridge. The flour is made into a fermented drink (or beer) in Nepal and in many parts of Africa. The straw from finger millet is used as animal fodder. The many benefits of ragi for health make it a desirable kitchen staple. A popular wheat replacement, it can be mixed with other grains like rice to prepare dosas, idlis etc. check some recipes from our cookbook here. The stomach and intestines are at peak levels of metabolism in the mornings. Consuming ragi-based foods for breakfast loads up the vitamins, antioxidants, fibre, and proteins with sufficient calories, thereby kick starting the digestive juice production. Ragi porridge, parathas, or upma are great options to begin your day right. Another great recipe that highlights ragi food benefits is Ragi malt, also called ambli or ragi java - a traditional drink from the state of Karnataka. Prepared with ragi flour and buttermilk, this cooling beverage comes together in less than 15 minutes and can be made savoury or sweet. Ragi java benefits are heightened in summers as it provides protection from the scorching heat. Ragi flour is cooked in water and then mixed with other simple ingredients such as plain buttermilk, salt, roasted cumin powder, asafoetida, curry leaves, coriander leaves, and onions to make a healthy, great digestive concoction (Vijaykumar, 2021).

Finger millet can be ground into a flour and cooked into cakes, puddings or porridge. The flour is made into a fermented drink (or beer) in Nepal and in many parts of Africa. The straw from finger millet is used as animal fodder (Wikipedia, 2023). The finger millet or ragi is malted and its grain is ground into flour. The flour is consumed with milk, boiled water, or yogurt. The flour is made into flatbreads, including thin, leavened dosa and thicker, unleavened roti. There are various food recipes of finger millet, including dosa, idli, and laddu. In southern India, on pediatrician's recommendation, finger millet is used in preparing baby food, because of millet's high nutritional content, especially iron and calcium. *Satva*, *pole* (dosa), *bhakri*, *ambil* (a sour porridge), and pappad are common dishes made using finger millet. In Karnataka, finger millet is generally consumed in the form of a porridge called *ragi mudde* in Kannada. It is the staple diet of many residents of South Karnataka. Mudde is prepared by cooking the ragi flour with water to achieve a dough-like consistency. This is then rolled into balls of desired size and consumed with sambar (huli), saaru or curries. Ragi is also used to make roti, idli, dosa and conjee. In the Malnad region of Karnataka, the whole ragi grain is soaked and the milk is extracted to make a dessert known as *keelsa*. A type of flat bread is prepared using finger millet flour (called *ragi rotti* in Kannada) in Northern districts of Karnataka. In Tamil Nadu, ragi is called *kezhvaragu* and also has other names like keppai, ragi, and ariyam. Ragi is dried, powdered, and boiled to form a thick mass that is allowed to cool. This is the famed *kali* or *keppai kali*. This is made into large balls to quantify the intake. It is taken with sambar or kuzhambu. For children, ragi is also fed with milk and sugar (malt). It is also made in the form of pancakes with chopped onions and tomatoes. *Kezhvaragu* is used to make puttu with jaggery or sugar. Ragi is called *koozh* – a staple diet in farming communities, eaten along with raw onions and green chillies. In Andhra Pradesh, *ragi sankati* or *ragi muddha* – ragi balls – are eaten in the morning with chilli, onions, and sambar. In Kerala, puttu, a traditional breakfast dish, can be made with ragi flour and grated coconut, which is then steamed in a cylindrical steamer. In the tribal and western hilly regions of Odisha, ragi or *mandiaa* is a staple food. In the Garhwal and Kumaon regions of Uttarakhand, *koda* or *maduwa* is made into thick rotis (served with ghee), and also made into *badi*, which is similar to halwa but without sugar. In the Kumaon region, ragi is traditionally fed to women after child birth. In some parts of Kumaon region the ragi flour is used to make various snacks like *namkeen sev*, *mathri* and *chips* (Wikipedia, 2023). Finger millet could be enjoyed in different forms and preparations. ragi roti, ragi dosa, ragi porridge, ragi upma, ragi cakes, ragi biscuits are few popular dishes of finger millet (ragi) (Vikaspedia, 2023).

In India the finger millet or ragi is malted and its grain is ground into flour. The flour is consumed with milk, boiled water, or yogurt. The flour is made into flat breads, including thin, leavened dosa and thicker, unleavened roti. There are various food recipes of finger millet, including dosa, idli, and laddu. In southern India, on pediatrician's recommendation, finger millet is used in preparing baby food, because of millet's high nutritional content, especially iron and calcium. Satva, pole (dosa), bhakri, ambil (a sour porridge), and pappad are common dishes made using finger millet. In Karnataka, finger millet is generally consumed in the form of a porridge called ragi mudde in Kannada. It is the staple diet of many residents of South Karnataka. Mudde is prepared by cooking the ragi flour with water to achieve a dough-like consistency. This is then rolled into balls of desired size and consumed with sambar (huli), saaru or curries. Ragi is also used to make roti, idli, dosa and conjee. In the Malnad region of Karnataka, the whole ragi grain is soaked and the milk is extracted to make a dessert known as keelsa. A type of flat bread is prepared using finger millet flour (called ragi rotti in Kannada) in Northern districts of Karnataka. In Tamil Nadu, ragi is called kezhvaragu and also has other names like keppai, ragi, and ariyam. Ragi is dried, powdered, and boiled to form a thick mass that is allowed to cool. This is the famed kali or keppai kali. This is made into large balls to quantify the intake. It is taken with sambar or kuzhambu. For children, ragi is also fed with milk and sugar (malt). It is also made in the form of pancakes with chopped onions and tomatoes. Kezhvaragu is used to make puttu with jaggery or sugar. Ragi is called koozh – a staple diet in farming communities, eaten along with raw onions and green chillies. In Andhra Pradesh, ragi sankati or ragi muddha – ragi balls – are eaten in the morning with chilli, onions, and sambar. In Kerala, puttu, a traditional breakfast dish, can be made with ragi flour and grated coconut, which is then steamed in a cylindrical steamer. In the tribal and western hilly regions of Odisha, ragi or mandiaa is a staple food. In the Garhwal and Kumaon region of Uttarakhand, koda or maddua is made into thick rotis (served with ghee), and also made into badi, which is similar to halwa but without sugar. In the Kumaon region of northern India, ragi is traditionally fed to women after child birth. In some parts of Kumaon region the ragi flour is used to make various snacks like namkeen sev and mathri **(Fig. 6)** (Wikipedia, 2023).

How to Prepare Finger Millet

Millet can be found in a variety of different forms. Dried millet, ground millet, and puffed millet are all common styles that can be found in supermarkets and health food stores. Dried millet is cooked similarly to rice or quinoa. Ground millet can be substituted for wheat flour, and puffed millet can be used in place of puffed rice. Finger millet is a healthy addition to most diets. Here are some ways to enjoy finger millet (WebMD EC, 2022):

- Use ground finger millet instead of wheat flour in pancakes
- Use millet instead of rice in stuffed peppers
- Make millet bread
- Use millet instead of bread in stuffing
- Use puffed millet to make marshmallow squares
- Try millet pilaf
- Include millet in curry

		
Mudde	**Roti**	**Poori**
		
Dosai	**Papad**	**Idli**
		
Malt	**Ladoo**	**Ragi puttu/steamed cake**

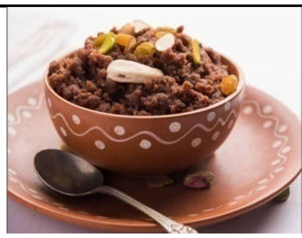
		
Cchips or wafers	**Bread**	**Cake**
		
Ragi wheat cookies	**Sweets**	**Halwa**
		
Ragi flour	**Ragi flakes**	**Ragi sprouts**

Fig. 6: Ragi products

BREEDING

Breeding objectives (Eagri, 2023):

1. Evolution of 80 days duration ragi suitable for irrigated conditions.
2. Breeding short duration drought resistant varieties suitable for rainsfed conditions
3. Breeding for high protein white ragi varieties suitable for malt making.
4. Blast resistant varieties.
5. Breeding varieties for sodic soils and tannery effluent affected soils.

Breeding techniques (Eagri, 2023)

1. Introduction
2. Selection
3. Hybridization and selection
4. Heterosis breeding :
5. Mutation breeding :

Traditional Breeding Methodologies and Limitations: Plant breeding is cultivar development, crop improvement and seed improvement of various agriculturally- and horticulturally-important crops, conventionally by selective mating or hybridization. Early finger millet breeding was largely confined to India, particularly in the southern states of Tamil Nadu, Karnataka and Andhra Pradesh. Later, it spread to other Indian states such as Maharashtra, Gujarat, Orissa, Bihar and Uttarakhand. The East African countries involved in finger millet breeding include Uganda, Zaire, Malawi and Zimbabwe. Finger millet breeding is also reported from Sri Lanka, Malaysia and the Philippines. In the European colonial period, indigenous crops were largely ignored. Yield levels were very low due to lack of inputs, poor soil fertility, rainfed farming, low-yielding cultivars and lack ofimproved agronomic practices. Initial breeding efforts in finger millet were limiteddue to its self-pollinating nature. Development of emasculation and pollination techniques created the opportunity to improve the crop and create new hybrids. Later, various breeding approaches such as pure-line selection, recombinationbreeding and mutation breeding were extensively used for the genetic improvementof finger millet. The breeding strategies for selection and genetic improvement havegreatly improved since the availability of genomic data and genome editing tools (Mirza and Marla, 2020).

Methods of Breeding (Mirza and Marla, 2020)

***Pure-Line Selection*:** The earliest reports of finger millet improvement are from India, where crop improvement was initiated by Leslie C. Coleman, the second director of agricultureof Mysore State in Karnataka. He initiated the work on pure-line selections from indigenous cultivars such as Hullubele, Gidda and others in 1913 at the Zonal Agricultural Research Station, V.C. Farm, Mandya and Hebbal farms, Bangalore. He contributed the first finger millet cv. H-22 in 1918 and his concerted efforts resulted in the release of several other cvs. such as K-1, R0870, ES-11, ES-13 CO-1 and H-1. Pure-line selection resulted in the development and release of several other cultivars of finger millet in India such as CO-2, CO-3, CO-7, CO-8, PLR-1, K-22, ES-11, RO-786, AKP6, VZM2 and Aruna. Three improved pure lines D-11 (early), D-31 (mid-late) and A-16 (late) were released at Hathkamba, Konkan in 1921.

***Hybridization Breeding*:** Finger millet genetic improvement got a boost after the establishment of hybridiza- tion techniques and several new cultivars were released. The aim of hybridization is to combine desirable genes found in two or more different plants or cultivars and to produce pure-breeding progeny superior to the parents. Using hybridization, four high-yielding cultivars were developed in India: Poorna (Co-1 x Aruna), Udaya (K-1 x Aruna), Annapurna (K-1 x Aruna) and Cauvery (Hulluble x H22). These cultivars showed up to 50% increase in yield potential and met to the needs of different finger millet growing seasons for a long time. Two more cultivars were developed through crossing, namely Shakti (Ro 013 x H22) and5–6 (Co-1 x H22). The development of high-yielding, white-grained finger millet also started in India at Coimbatore, Tamil Nadu (Wariar and Divakaran 1956). The first improved cv. E.C. 4310 was created by a cross between E.C. 1540 (low-yielding, white- grained strain, high vitamin-13 content) with male parent E.C. 985 (high-yielding, brown-grained). A coordinated finger millet improvement program was initiated in India in 1963 to evaluate, screen and catalogue the 947 stocks of world collections. The contributions of Indian breeder C.H. Lakshmanaiah to finger millet crop improvement are unparalleled. At the VC Farm, Mandya, Karnataka in 1964 he created new recombinant cultivars by crossing Indian cultivars with African ecotypes. A few African donor parents such as IE-927, IE-929, IE-980, IR-810 andIE-902 were identified by screening the available world collection of germplasmover 8 years. He crossed these lines with the local cvs. such as Hallubele, K1, Annapurna, Purna, Cauvery, Shakti, Co-1 and Hamsa. The hybridization resulted in 16 Indo-African cultivars with substantially more yield potential and these weredesignated as "Indaf" cultivars. These can be grown under both irrigated and rainfed conditions (Bhat et al. 2018; Lakshmanaiah 1967).

Mutation Breeding: Mutation breeding has been around since the 1930s. It is a powerful means of creat-ing useful genetic variability. Mutation breeding simply accelerates the process of mutation in plant genetic material which otherwise is underway in nature. Mutationbreeding is based on selfing of mutants instead of crossing as in conventional breed-ing, until the induced character has a stable expression in the subsequent mutant generations. It is cost effective, quick, robust, transferrable and ubiquitously applicable. There are more than 3200 mutant cultivars of more than 210 plant species from over 70 countries, including 2 cultivars of finger millet (FMM165, FMM175) from Zambia, registered in the FAO/IAEA Mutant Varieties Database (https://mvd.iaea.org/) and released for commercial use. The most common method of mutationbreeding is to treat seeds with physical, chemical or a combination of both mutagens and selecting from the subsequent population the desirable mutants which are superior to their parents.

Improved Cultivars (Mirza and Marla, 2020). Between 1986 and 1999 in India, the main focus was on developing cultivars with high grain and straw yield, as well as drought and disease resistance. Several hybrids as well as pure-line high-yielding cultivars (1500–5000 kg/ha) such as MR-2; MR-6; Indaf-15; VL124; HR911 (UAS1 x IE 927); L-5 (Malawi x Indaf9); Gautami (PR 1158–9) (PR 202 x U22) and Gujarat nagli 2 (NS 109) (Pureline selection) were released from different research centers. Blast-resistant cvs. GPU 28, Indaf 5 (Indaf 9 x IE 1012) and KM 65 and two drought tolerant cvs. RAU 8 (BR 407 x Ranchi Local) GN 3 (KM 13 x GN 2) were released.

Two cultivars, a pureline Suraj (VR 520) and a hybrid Saptagiri (or PR 2614) (MR 1 x Kalyani), were developed in Andhra Pradesh with both blast and drought tolerance. Another cultivar, PR 230 (or Maruthi) with both blast and blight resistance was developed through pure-line selection at ANGRAU, Paleru, A.P. A salinity tolerant cultivar, TRY 1, was developed at TNAU, Coimbatore. In the period 2000–2018, with the establishment of the AICRP on small millets, emphasis was on developing hybrid cultivars involving productive lines with elite backgrounds. Both early-maturing and long-duration cultivars with high yieldpotential and suitable for irrigated or rainfed conditions were released. Most of the cultivars were resistant to blast (neck and finger) disease. Numerous blast resistant cultivars of *GPU* and *KMR* series i.e. GPU-26, GPU-28, GPU-45, GPU-48, GPU- 66, KMR-204, KMR-301 and KMR-340, with average yields of 2000–4000 kg/ha were released by AICRP (1986–2018). A semi-dwarf, non-lodging cv. GPU-67 was also released which is suitable for cultivation in all finger millet growing regions. Breeders also focused on tolerance to brown spot disease, stem borers and aphids. A somaclonal cv. Dapoli-2 (SCN-6) was developed through tissue culture at Dr. BSKKV, Dapoli, Maharashtra and released in 2017. The parentcv. Dapoli-1 (1985) was mid-late (125–135 days), non-lodging and responsive to nitrogenous fertilizers and with reddish brown grain color. The somaclone Dapoli-2 is a high-yielding cultivar rich in iron and calcium, moderately resistant to blast and tolerant to aphids and tobacco cutworm (*Spodopter littura*). Released varieties of ragi in India is furnished in Table 2 (Millets, 2023).

Table 2. Released varieties of ragi in India (1986-2016)

Crop/Variety	Pedigree	Institute where developed	Year of release	Maturity (Days)	Av Yield Q/ha	Area of Adaption	Special features
VL 376	GE 4172 x VL Ragi 149	ICAR-VPKAS, Almora	2016	103-109	29-31	All Ragi growing areas of country	Responsive to fertilizer and moderately resistant to blast.
GNN-6	Selection from local germplasm WN-259	Waghai, Navsari Agricultural University	2016	120-130	28-30	Gujarat	Moderately resistant to leaf blast and finger blast
GN-5	Selection from local germplasm WWN-20	Waghai, Navsari Agricultural University	2016	120-130	25-27	Gujarat	Late maturing, White colour seed, Moderately resistant to leaf and finger blast.
VL Mandua - 348	VL Ragi 146 x VL Ragi 149	ICAR-VPKAS, Almora	2016	104-112	18-20	Uttarakhand	Suitable for organic cultivation; Resistant to neck and finger blast; and tolerant to lodging; light copper grains.
KMR 340	OUAT-2 x WRT-4	VC Farm, Mandya, UAS,Bengaluru	2016	90-95	35-40	Karnataka	White ragi variety, specially for confectionary purpose, resistant to blast and blight diseases, tolerant to stem borer and aphids
OEB 532	GPU-26 x L-5	OAUT, Bhubaneswar	2012	110-115	22-25	Odisha, Bihar, Chattisgarh, Karnataka,	Moderately resistant to blast diseases.

KMR 204	GPU 26 x GE-1409	VC Farm, Mandya, UAS,Bengaluru	2012	100-105	30-35	Karnataka	Early duration variety
VR 936	IE 2695 x PR 202	ANGRAU, Vizianagaram	2012	115-120	28-30	Andhra Pradesh	Suitable for late conditions. Responsive to nitrogenous fertilizers.
PPR 2700 (Vakula)	KM 55 x U22/B	ARS Perumallapalle A.P.	2012	105-110	25-30	Andhra Pradesh	Resistant to leaf blast and tolerant to drought.
Indira Ragi 1	HR 911 x GE 669	Jagdalpur, IGKVV	2012	120-125	25-26	Chattisgarh	Non-shattering, non-lodging, responsive to fertilizers.
VL 352	VR 708 x VL-149	ICAR-VPKAS, Almora	2012	95-100	33-35	All Ragi growing areas of country	Moderately resistant to blast.
KOPN 235	Selection from local germplasm	MPKVV, Rahuri	2011	115-120	25-26	Sub mountain and ghat zone of Maharashtra	Resistant to blast
OEB 526	SDFM 30 x PE 244	OAUT, Bhubaneswar	2011	110-115	25-26	Odisha, Bihar, Chattisgarh, Karnataka, Tamilnadu	Moderately resistant to leaf, neck and finger blast diseases.
GPU 66	PR 202 x GPU 28	PC Unit, Bengaluru	2009	112-115	35-40	Karnataka	Green plant parts with narrow leaves, medium compact ears with tip incurved fingers
GPU 67	Selection from germplasm accession GE 5331	PC Unit, Bengaluru	2009	114-118	30-35	National	Non lodging (Semi dwarf)
Srichaitanya (VR 847)	GPU 26 x L 5	ANGRAU, Vizianagaram	2009	110-115	26-28	Andhra Pradesh	Moderately resistant to blast
KMR 301	MR 1 x GE 1409	VC Farm, Mandya,	2009	120-125	55-60	Southern Dry zone of	High grain and straw
PRM 1	Selection from Ekeshwar of PauriGarhwal Region	Hill Campus, GBPUA& T, Ranichauri	2006	110-115	20-25	Hills of Uttarakhand	Resistant to blast
Bharathi (VR 762)	Pure line selection from VMEC 134	ANGRAU, Vizianagaram	2006	110-115	26-30	Andhra Pradesh	Moderately resistant to blast
GPU 48	GPU 26 x L 5	PC Unit, UAS, Bangalore	2005	95-100	30-35	Karnataka	Early, high yield, blast resistant Suitable for summer also
GPU 48	GPU 26 x L 5	PC Unit, Bengaluru	2005	95-100	28-30	Karnataka	Pigmentation on all plant parts and highly resistant to blast
TNAU 946		TNAU, Coimbatore	2004	105-115	20-25	Tamil nadu	-
VL 315	SDFM 69 x VL 231	VPKAS, Almora	2004	105-115	26-28	Uttaranchal	Moderately resistant to finger and neck blast
GPU 45	GPU 26 x L 5	PC Unit, UAS, Bangalore	2001	95-100	27-29	Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra	Early, blast resistant
Chilika (OEB 10)	GE 68 x GE 156	OUAT, Bhubaneshwar Odisha	2001	115-120	26-27	Odisha, Madhya Pradesh, Gujarat, Andhra Pradesh and Tamil Nadu	Moderately resistant to blast, resistant to stem borer, late variety
GPU 26	(I-5 x I-9) x IE 1012	PC Unit, UAS, Bangalore	2000	100-105	30-35	Karnataka	Early, blast tolerant, suitable late sowings &summer
BM 9-1	Mutant from BudhaMandia	OUAT, Berhampur	1999	103-105	25-30	Karnataka, Andhra Pradesh, Odisha, Madhya Pradesh &	Moderately resistant to blast and brown spot
						Maharashtra	
L-5	Malawi x Indaf 9	UAS, Bangalore	1999	120-125	35-40	Karnataka	Late variety, for early sowings
Champavathi (VR 708)	Puerline selection from VMEC 36	ANGRAU, ARS Vizianagaram	1998	90-95	20-25	Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Odisha	Photo insensitive& early maturity
MR 1	Hamsa x IE 927	V.C. Farm Mandya UAS, Bangalore	1998	125-130	35-40	Karnataka	Long duration, for early sowings
PR 230 (Maruthi)	Pure line selection	ANGRAU, Paleru	1998	90-100	25-30	Andhra Pradesh (Telangana region)	Resistant to blast and blight
GPU 28	Indaf 5 x (Indaf 9 x IE 1012)	PC Unit, Bangalore	1996	110-115	35-40	Karnataka	Highly blast resistant
VL-146	VL 201 x IE 882	VPKAS, Almora	1995	95-100	25-30	Uttar Pradesh, Jharkhand, Odisha, Uttarakhand, Maharashtra, Madhya Pradesh, Karnataka	Early maturity
BM 2	PurelineSelection	BAU, Ranchi	1995	105-110	24-26	Bihar	Resistant to neck & finger blast
Saptagiri (PR 2614)	MR 1 x Kalyani	APAU, Perumallapalle	1995	110-115	25-30	Tamil Nadu, Maharashtra, Odisha, Andhra Pradesh	Resistant to blast & tolerant to drought
Dapoli 1	Selection from mutant No. 50-1	KVK, Dapoli	1994	100-110	15-20	Konkan regions of Maharashtra	Early maturity
Suraj (VR 520)	Pureline selection from VM 2507/19	ANGRAU, Vizianagaram (AP)	1994	90-95	22-28	All over India	Early maturity, resistant to blast and tolerant to drought
KM 65	Selection from exotic germplasm	CSAUA&T, Kanpur	1994	98-102	18-21	Uttar Pradesh	Early maturity resistant to Blast
A 404	Selection from germplasm	BAU, Ranchi	1993	110-115	22-25	Bihar	Moderately resistant to blast
Gautami	PR 202 x U22	MRS, Vizianagaram	1993	115-120	28-30	Andhra Pradesh	Tolerance to blast,

(PR 1158-9)							high yield
GN 3	KM 13 x GN 2	GAU, Gujarat	1993	130-136	22-25	Gujarat	Tolerant to drought long duration
Padmavathi (PPR 2350)	Pureline selection	ANGRAU, Perumallapalle (AP)	1993	110-115	25-30	Coastal Andhra Pradesh	Suitable for late kharif
Indaf 15	IE 67 x IE 927	V.C. Farm Mandya UAS, Bangalore	1991	110-115	35-40	Karnataka	Long duration/ Late maturity
VL 149	VL 204 x IE 882	VPKAS, Almora	1991	98-102	20-25	All states	Wide adaptation, earliness
KM 13	Pureline selection	CSAUA&T, Kanpur	1989	95-110	25-30	Uttar Pradesh, Madhya Pradesh, Odisha	Early maturity
PES 400	Pureline selection	GBPUA&T, Pantnagar	1989	98-102	18-20	Hills of U.P	Early maturity
Co 13	Co 7 x TAH 107	TNAU, Coimbatore	1989	95-100	25-30	Tamil Nadu	Early maturity
TRY 1	Selection from HR 374	TNAU, Coimbatore	1989	100-105	20-25	Tamil Nadu	Tolerant to salinity
VL 124	Selection from local germplasm	VPKAS, Almora	1989	95-100	20-25	Hills of U.P	Earliness, high seed and fodder yield
RAU 8	BR 407 x Ranchi Local	RAU, Dholi	1989	105-110	22-25	Bihar and other states	Tolerant to drought
Gujarat nagli 2 (NS 109)	Pureline selection	GAU SardarKrishinagar Gujarat	1988	110-115	25-30	Gujarat	High finger number
Indaf 9	K1 x IE 980 R	V.C. Farm Mandya UAS, Bangalore	1988	100-105	30-35	Karnataka	For late sown conditions in Kharif
HR 911	UAS 1 x IE 927	PC Unit, Bangalore	1986	110-115	40-50	Karnataka	It can be grown in rainfed and irrigated conditions
Indaf 8	Hullubele x IE 929	V.C. Farm Mandya UAS, Bangalore	1986	120-125	35-40	Karnataka	Long duration type for early sowings

Breeding work in India: The major centers of ragi breeding in India have been firstly, Coimbatorc, Tamil Nadu, with secondary breeding and testing centers at Anakapalle and at Koilpatti in the south part of the State. In Karnataka , much of the breeding work has been carried out at Hebbal near Bangalore, at Mandya about sixty miles south of Bangalore and to a limited extent, mainly for testing, at Karwar at the edge of the Western Ghats. In Andhr a Pradesh, the millet breeder is headquartered at Guntur in the east, but work is also carried out at Visakhapalnam and in Ghittoor. In Maharashtra , the major center for crop research has been Poona with subsidiary centers elsewhere. In Gujarat, the work on ragi has been carried out to a limited extent at a place called Waghai in the south-eastern part of the State. The Indian Agricultural Research Institute at New Delhi has done relatively little breeding work but has in recent years concentrated more on fundamental aspects related to maintaining the world collection and in respect to grain quality. Some work on this crop has also been done in the Himalayan foothills of Utta r Pradesh, in Bihar and Orissa (Rachic and Peter, 1977).

NUTRITIVE VALUE

Finger millet is considered one of the most nutritious cereals. Finger millet contains about 5–8% protein, 1–2% ether extractives, 65–75% carbohydrates, 15–20% dietary fiber and 2.5–3.5% minerals. Of all the cereals and millets, finger millet has the highest amount of calcium (344 mg%) and potassium (408 mg%). The cereal has low fat content (1.3%) and contains mainly unsaturated fat. 100 grams of Finger millet has roughly on an average of 336 kcal of energy in them. However, the millet also contains phytates (0.48%), polyphenols, tannins (0.61%), trypsin inhibitory factors, and dietary fiber, which were once considered as "anti nutrients" due to their metal chelating and enzyme inhibition activities (Thompson 1993) but nowadays they are termed as neutraceuticals. Being non-glutinous, finger millet is safe for people suffering from gluten allergy and celiac disease. It is non-acid forming, and hence easy to digest. Finger millet is rich in amino acids (Tryptophan, Threonine, Valine, Isoleucine and Methionoine) (Vikaspedia, 2020). Finger millet grains has a high carbohydrate content of 81.5%, protein 9.8%, crude fiber 4.3% and mineral 2.7%which is comparable to other cereals like rice, wheat, maize and millet. The crude fiber and mineral content of finger millet is remarkably higher than those of wheat (1.2% fibre, 1.5% minerals) and rice (0.2% fiber and 0.6 % minerals). About 80-85% of the finger millet starch is amylopectin and remaining (5-20%) is amylose. The quality of protein is mainly its essential amino acids. Finger millet contains 44.7% essential amino acids. Among all of the cereals and millets, finger millet has the highest amount of calcium (344 mg %) and potassium (408 mg %). The total ash content found in finger millet is nearly 1.7 to 4.13% which is higher than any other commonly consumed cereal grains. Finger millet is the good source of calcium and iron. Finger millet plays an important role in our diet as it is the richest source of calcium and iron, finger millet helps to overcome the calcium deficiency leading to bone and teeth disorder and iron deficiency leading to anemia (Karki *et al*., 2020). Ragi is a rich source of calcium, iron, protein, fiber and other minerals. The cereal has low fat content and contains mainly unsaturated fat. It is easy to digest and does not contain gluten. Finger millet is considered one of the most nutritious cereals which helps in keeping weight in control, maintaining bone health, lowering blood cholesterol, control anaemia and for diabetics because of lower glycemic response *i.e.*, lower ability to increase blood sugar level. Ragi is rich in amino acids which are vital in normal functioning of body and are essential for repairing body tissues. If consumed regularly, ragi could help in keeping malnutrition, degenerative diseases and premature aging at bay. Green ragi is recommended for conditions of blood pressure, liver disorders, asthma, lactating mother and heart weakness. Its high intake could increase quantity of oxalic acid in the body. Therefore, it is not advised to patients having kidney stones. Finger millet can be value added to prepare cakes, roti, dosa, porridge, upma, pitha, halwa, biscuits from the powder of ragi (Das, 2020).

It is rich in polyphenols and particularly in calcium. The double headed trypsin, α-amylase inhibitor from this grain has been isolated and characterized extensively. One major use for the grain is the making of fermented beverages after malting. α-Amylase and β-amylase are produced during germination. Food made from malted ragi is traditionally used for weaning and has been the source of low viscosity weaning foods that can deliver more energy per feed than those based on gelatinized starch. There is some evidence that foods from finger millet have a low gylcaemic index and are good for diabetic patients. Decortication, puffing, extrusion, and expansion are some of the new uses that the grain has been put to. Finger millet plays a vital role in the food and nutritional security of many people in developing countries particularly in Asia and Africa. It is a staple food for poor people in many regions of Asian (India, China, Nepal, and Sri Lanka) and African (South Africa, Ethiopia, Kenya, Uganda, and Nigeria) countries. Finger millet contains nutrient rich components such as dietary fibers, minerals, vitamins, and phytochemicals that include phenolic compounds with several potential health benefits. Calcium (Ca) is an important macronutrient for healthy life of plants, humans and animals. It plays an indispensable role in structure and signaling and its deficiency causes low bone density, osteoporosis, colon cancer etc. Finger millet grains contain exceptionally higher amount of Ca (>300 mg/100 g) when compared to other major cereals. Ca transporter and sensor family genes are involved in the uptake, transport and accumulation of Ca (Maharajan *et al*., 2021). Finger millet is rich in niacin, which plays an important role in more than 400 enzyme reactions. Niacin is important to maintaining the health of your skin, blood, and organs. Niacin is frequently added to foods as a supplement because it is such an important micronutrient. Finger millet is also an excellent source of: Vitamin A, Vitamin B, Niacin, Calcium, Iron, Phosphorus, Potassium and Antioxidants (WebMDEC, 2022). Nutritional value per 100 g of Finger millet is given in Table 3 (Wikipedia, 2023).

Table 3. Nutritional value per 100 g of finger millet

Energy	1,283 kJ (307 kcal)
Carbohydrates	53.5 g
Dietary fiber	22.6 g
Fat	1.9 g
Protein	7.4 g
Minerals	Quantity %DV†
Calcium	34% 344 mg
Iron	87% 11.3 mg
Magnesium	43% 154 mg
Phosphorus	26% 183 mg
Potassium	11% 538 mg
Sodium	0% 2 mg
Zinc	18% 1.7 mg
Other constituents	Quantity
Water	11 g

Finger millet is 11% water, 7% protein, 54% carbohydrates, and 2% fat. In a 100 gram reference amount, finger millet supplies 305 calories, and is a rich source (20% or more of the Daily Value, DV) of dietary fiber and several dietary minerals, especially iron at 87% DV (Wikipedia, 2023). Finger millet is considered one of the most nutritious cereals. Finger millet contains about 5–8% protein, 1–2% ether extractives, 65–75% carbohydrates, 15–20% dietary fiber and 2.5–3.5% minerals. Of all the cereals and millets, finger millet has the highest amount of calcium (344 mg%) and potassium (408mg%). The cereal has low fat content (1.3%) and contains mainly unsaturated fat. 100 grams of Finger millet has roughly on an average of 336 kcal of energy in them. However, the millet also contains phytates (0.48%), polyphenols, tannins (0.61%), trypsin inhibitory factors, and dietary fiber, which were once considered as "anti nutrients" due to their metal chelating and enzyme inhibition activities but nowadays they are termed as neutraceuticals. Being non-glutinous, finger millet is safe for people suffering from gluten allergy and celiac disease. It is non-acid forming, and hence easy to digest. Finger millet is rich in amino acids (Tryptophan, Threonine, Valine, Isoleucine and Methionoine) (Vikaspedia, 2023).

HEALTH BENEFITS

Finger millet is an excellent source of natural calcium which helps in strengthening bones for growing children and aging people. Regular consumption of finger millet is good for bone health and keeps diseases such as osteoporosis at bay and could reduce risk of fracture. It is now established that phytates, polyphenols and tannins can contribute to antioxidant activity of the millet foods, which is an important factor in health, aging and metabolic diseases. Finger millet's phytochemicals help in slowing digestion process. This helps in controlling blood sugar level in condition of diabetes. It has been found that finger millet based diet helps diabetics as it contains higher fibre than rice and wheat. Also, the study found that diet based on whole finger millet has lower glycemic response i.e. lower ability to increase blood sugar level. This is due to presence of factors in finger millet flour which lower digestibility and absorption of starch. Because of its high nutritional content ragi flour is recommended as a weaning food especially in the southern parts of India. Finger millet is a very good source of natural Iron and its consumption helps in recovery of anemia. The ragi based foods are highly suited for expectant mothers and elderly due to their high calcium and iron content. Finger millet consumption helps in relaxing body naturally. It is beneficial in conditions of anxiety, depression and insomnia. It is also useful for migraines. Green ragi (finger millet) is recommended for conditions of blood pressure, liver disorders, asthma and heart weakness. Green ragi is also recommended to lactating mothers in condition of lack of milk production. If consumed regularly, finger millet could help in keeping malnutrition, degenerative diseases and premature aging at bay. So, finger millet is an extremely nutritious cereal and is very beneficial for maintaining a good health. Therefore have received attention for their potential role as functional foods. However, its high intake could increase quantity oxalic acid in the body. Therefore, it is not advised to patients having kidney stones (Urinary calculi). Finger millet could be enjoyed in different forms and preparations. ragi roti, ragi dosa, ragi porridge, ragi upma, ragi cakes, ragi biscuits are few popular dishes of finger millet (ragi) (Vikaspedia, 2020). Finger millet is good for infants, elderly and pregnant women. It is also very good for lactating women as it helps in producing sufficient amount of breast milk for feeding their babies. Finger millet also helps to increase the level if haemoglobin and helps to fight against malnutrition and degenerative disease (Karki *et al*., 2020). Ragi is an excellent source of proteins, minerals, vitamins and calcium. Ayurveda also mentions the benefits of ragi for cholesterol management owing to its Ama (toxin) reducing properties. Ragi flakes for breakfast and Ragi flour chapatis both are great for weight management due to their high fibre content:

- **Protein and fibre source**: Vegetarians and their fight to include more protein in their diets is a constant tussle. Including Ragi in daily diet can help vegetarians resolve this as 100 grams of whole ragi flour provides over 7 gms of pure protein and 16 gms of fibre. Owing to its high fibre content, Ragi or Nachni, prevents overeating and keeps you full for a longer time, and this aids in weight loss. Ragi porridge is considered as a great food option for infants and young kids to regulate their bowel movements. The insoluble fibre in Ragi helps ease the movement of foods in the stomach and adds bulk to the stool, facilitating better digestion and relieving constipation.
- **Calcium rich**: When we talk calcium, milk or milk products are considered the only sources for its intake. However, that's not completely true! Ragi flour is one of the greatest non-dairy calcium sources when compared to other grains. Calcium is the building block for strong bones and teeth, as well as the prevention of bone-weakening conditions like arthritis and osteoporosis. When sprouted, the calcium content in ragi is increased by 20 percent. Sprouting also reduces anti-nutritional factors and helps in better absorption of calcium. This again makes Ragi a great option for baby food.
- **Red blood cells production**: Naturally rich in iron, ragi food benefits those with low levels of haemoglobin. Ragi is also rich in vitamin B1, which helps in the synthesis of red blood cells and generates adenosine triphosphate (ATP), which helps in energy build-up in the

body. A lot of times, even consuming foods rich in iron does not help anaemic patients as the level of absorption is poor. Ragi, especially when sprouted, has high levels of vitamin C, which is known to improve iron absorption.

- **Great for diabetes control**: Ragi is rich in dietary fibre and thus lessens the cravings for food. In comparison to wheat and other flours, it creates a far lesser spike in blood sugar levels. Ragi is also rich in magnesium which helps the pancreas produce enough insulin to control blood sugar, thus improving insulin sensitivity.
- **Gluten-free:** The many Ragi uses and benefits also extend to those suffering from celiac disease or gluten intolerance as well. Being naturally gluten-free, ragi is a great wheat substitute for chapatis, dosas, idlis and more. This gives a host of meal options to those on a gluten-free diet.
- **Antioxidant storehouse**: Ragi is rich in antioxidants which increase immunity and fight against infections. It also aids the body's natural ability to relax as it is a rich source of amino acids, which helps combat headaches, insomnia and even depression.
- **Great pick for the little ones and new moms:** The many benefits of ragi for health also make it a great choice for both infants and new moms. Both of them need tender care, and along with their digestion, Ragi also strengthens their bones and promotes overall growth of babies. From stimulating milk production in new moms to balancing hormonal processes in pregnant women, the uses of ragi are abundant due to its high iron and calcium content.
- **Youthful and healthy skin**: The essential amino acids Methionine and Lysine and vitamins such as Vitamin B3 present in Ragi work miracles in keeping the skin youthful and healthy. The amino acids make skin tissues less susceptible to wrinkles and ageing and also help in the creation and maintenance of collagen in the body. This millet impedes cross-linking of collagen, which in turn helps the skin to possess its elasticity. So if you want to minimise the effects of ageing and have good skin for longer, adding this wonder food to your daily diet is advisable. Ragi also contains a good amount of calcium and Vitamin E, which helps form new and healthy skin and aid in healing scars. Vitamin E helps in preventing skin damage, moisturising the skin and in creating a protective layer that allows your skin to be healthy and shiny. Apply a paste of Ragi flour mixed with milk on the face to get rid of wrinkles. Ditch the sunscreen and switch to eating ragi daily as it helps guard the skin against harmful sun rays, preventing skin cancer. The presence of Vitamin C & E and selenium in ragi also helps lighten the skin complexion and hydrates the skin. Ragi has phenolic acid and other antioxidants that prevent ageing, while Methionine helps develop healthy skin and hair in babies. No wonder ragi is steadily becoming a favourite when it comes to buying organic food products online.
- **Great hair goals:** Instead of experimenting with harsh shampoos and oils to get perfect hair, eating nutritionally-rich food can help improve your hair health. Here, ragi is an excellent food item to add to your diet. Ragi benefits for hair start with its rich protein content that prevents hair loss. A better idea than hunting for protein-based shampoos is to consume foods that supply natural protein to your hair and nourish it. Consume ragi for hair growth and to strengthen your hair. It also benefits people suffering from hair loss. Plus, it promotes blood circulation in the scalp and stimulates healthy hair growth. Ragi is also a natural relaxant and helps reduce hair fall due to stress. Ragi benefits for hair also extend to treating scalp related conditions like dandruff, psoriasis, itchiness and eczema with its magnesium content and anti-inflammatory properties. It lowers the level of cortisol in the body, which helps control hair fall. Oxidation of tissues is known to cause greying of hair and the host of antioxidants present in finger millet help prevent this. They are also used for the treatment of premature balding.

The vitamins, minerals, and fiber found in finger millet can provide important health benefits. The potassium found in finger millet can help keep your kidneys and heart functioning properly. Potassium also helps your nerves transmit signals, which allows your brain and your muscles to work together smoothly. Finger millet is also an excellent source of B vitamins, which play a role in everything from brain function to healthy cell division. B vitamins are even connected to a reduction in fatigue. In addition, finger millet can provide other health benefits like (WebMD EC, 2022):

Heart Health: Whole grains like finger millet are connected to lower risk of heart disease. Finger millet is full of dietary fiber, which helps to control the"bad" cholesterol that can contribute to heart diseases like atherosclerosis. Soluble fiber absorbs cholesterol before it enters your bloodstream, maintaining a lower cholesterol level without medication. Millet has also been shown to raise "good" cholesterol levels and lower triglycerides, which are a kind of fat found in your blood. Cholesterol levels are one of the biggest risk factors for heart disease, so eating millet regularly may help keep your heart healthier.

Diabetes Control: Finger millet has a lowglycemicindex. That means that it has lower levels of simple sugars and higher levels of complex carbohydrates, which take a longer time to digest. Foods with a low glycemic index can help prevent your blood glucose level from spiking after a meal. As a result, eating millet — instead of high glycemic index foods like white wheat flour — can help people living with diabetes manage their blood sugar levels.

Digestive Health: The fiber in finger millet can also help support your digestive health. Insoluble dietary fiber is "prebiotic," meaning it helps support the good bacteria in your gut. Eating prebiotics like the fiber in millet can support gut health by keeping your digestive flora healthy. Eating enough fiber has also been linked to a decreased risk of colon cancer.

Toshi (2023) has given the following Health Benefits of Ragi:

- High protein: Eleusinian is the major protein content that is found in ragi and has a lot of biological value. This protein helps prevent malnutrition and is considered to be a healthy source of protein for vegetarians. Methionine content constitutes 5 per cent of the total protein found in ragi. Ragi has been grown for hundreds of years and it can grow in high altitudes and withstand harsh weather conditions. Ragi has a lot of carbohydrates and is placed at the peak of food grains by most dietitians. Ragi cannot be polished like other grains because it is too tiny and this makes it possible for us to consume it in its purest form.
- Natural weight loss agent: Ragi has high amounts of fibre in it that keeps your stomach full and stops you from unwanted cravings. This helps in weight loss. It reduces the level of blood sugar in your body and turns it into insulin. Ragi is best suited when you consume it in the morning. Ragi contains a type of amino acid called Tryptophan that helps you lose weight. Tryptophan reduces your appetite and thus you don't feel hungry often.
- Prevents your skin from ageing: Ragi is a natural skincare agent and an anti-ageing cereal. Important amino acids like Methionine and Lysine are present in ragi that protects your skin from risks of rashes, wrinkles and skin dullness. The antioxidants found in ragi fight stress in your body that help reverse the signs of ageing. It rejuvenates the skin cells, thus making you look fresh and healthy. Ragi also has Vitamin E, which is very useful for your skin. Vitamin E acts as a natural assistant for body wounds. This help lubricates the skin, forming a protective layer that enables your skin to grow.

- Ragi is good for your hair: Ragi is rich in proteins and helps prevent hair loss. It is highly recommended for people suffering from hair loss. Your hair requires a lot of protein because hair itself is made of protein. Keratin is the main protein found in your hair. Lack of protein can lead to loss of hair and if you begin consuming ragi, it will strengthen your hair and reduce hair fall. Ragi is also said to prevent premature greying of hair. This is usually caused due to the oxidation of tissues, and the antioxidants present in ragi will effectively prevent the damage to tissues, thereby, reducing the possibility of having grey hair. Magnesium content can be found in ragi that is responsible for controlling hair loss. Ragi also increases blood circulation in your body that helps in hair growth.
- Ragi has loads of calcium: There is no cereal that comes close to the amount of calcium available in ragi. Calcium is needed for human bones to develop and prevents osteoporosis, meaning bones become weak and fragile. So instead of popping calcium pills, it is recommended that you drink ragi porridge (ragi kanji). 100 grams of ragi consists of 344 milligrams of calcium which is high and very good for your bones.
- Increases production of mother's milk: Lactating women must consume more green ragi as it increases haemoglobin levels thus increasing the production of mother's milk among women. This also called increased levels of lactation. A lactating mother must add green ragi to her daily diet and it will increase amino acids and breast milk, calcium and iron which is very important for the mother and the child.
- Prevents diabetes: Regular consumption of ragi can help reduce your risk of diabetes. This is because polyphenols and dietary fibres are prevalent in ragi. Ragi has huge amounts of fibre when compared to other whole wheat grains. Consuming ragi on a regular basis lowers the level of blood sugar and stabilises your sugar level. Ragi acts as an absorbent such that it absorbs starch and lowers the digestibility of your body. This is why most people who consume ragi don't feel hungry very often.
- Good digestion: The dietary fibre present in ragi helps your intestines digest food smoothly. Ragi improves the movement of food in your body, such that, it smoothens the flow of food through your intestines and retains the water in your body for the purpose of waste excretion. Thus ragi is a highly nutritional cereal and helps you maintain good health. However, you can relish different ragi dishes and ensure you have a healthy life. Ranging from dosas to ragi balls, this healthy cereal will keep you fit and healthy all day all long.
- Ragi keeps you relaxed: One amazing benefit of eating ragi is that it acts as a natural relaxant for your body. Consuming ragi helps you deal with anxiety, insomnia and depression. It stabilizes all of these anxiety disorders and keeps you relaxed the whole day. It does cool your thinking and keeps you calm. Literally, ragi acts as a coolant for your body on a hot summer day.
- Prevents colon cancer: Ragi is known to help prevent cancer because it contains fibre and phytonutrients that prevent the risk of colon cancer. Lignan, a type of nutrient found in ragi is converted into mammalian lignan by your intestine and this protects women from the risk of having breast cancer. Consuming ragi daily can reduce our risks of developing cancer.

Isha (2023) has given the following Health Benefits of Ragi:

Ragi has High Protein Content: The grain's protein content is comparable to that of rice. However, some ragi varieties have shown double that level. More importantly, this protein content is quite unique. The main protein fraction is eleusinin, which has a high biological value, meaning that it is easily incorporated into the body. There are also significant quantities of tryptophan, cystine, methionine and total aromatic amino acids. If that sounds too complicated, all you need to know is that these are considered crucial to human health, and that most cereals are deficient in these components. This high protein content makes finger millet a very important factor in preventing malnutrition. The cereal can be an especially good source of protein for vegetarians because of its methionine content that constitutes about 5% of the protein.

Ragi is a Rich Source of Minerals: Ragi is also a very rich source of minerals. It has been found to have between 5-30 times the calcium content found in other cereals. It is also rich in phosphorus, potassium and iron. Calcium is of course an important component in maintaining bone density and health. Thus, finger millet would be a healthier alternative to over-the-counter supplements, especially for people who might be at risk of osteoporosis or low hemoglobin levels. The study, "The Lost Crops of Africa," published by the United States National Academies sees finger millet as a potential "super cereal" and points out that "the world's attitude towards finger millet must be reversed. Of all major cereals, this crop is one of the most nutritious." The study notes that people in Uganda and southern Sudan have healthy, strapping physiques despite eating just one meal a day, and attributes this to finger millet.

Ragi Controls Diabetes: The rapid rise in the prevalence of diabetes has led to a great demand for foods containing complex carbohydrates with high dietary fiber levels and beneficial phytochemicals. Phytochemicals are a varied group of chemical compounds derived from plants, which are considered to be important factors in our capacity to combat disease. All these components are usually found in the outer layer of the grain or the seed coat, and so, it is generally a good idea to consume whole grains. Especially with finger millet, the grain's seed coat is richer in polyphenols as compared to grains such as barley, rice, maize and wheat. For example, it has 40 times the phenolic content of rice and 5 times that of wheat. Among the millets, it is comparable to foxtail millet, and second only to kodo millet. Initial studies have also shown that finger millet controls blood glucose levels, and hyperglycemic and oxidative stress. Finger millet has also shown promise in accelerating wound healing among diabetics.

Ragi has Anti-microbial Properties: Finger millet has been found to act against a number of bacteria including Bacillus cereus, which causes food poisoning, Salmonella sp., which causes a typhoid-like fever, and Staphylococcus aureus, one of the primary causes of skin and soft tissue infections such as abscesses, furuncles, and cellulitis.

Ragi has Anti-cancer Potential: Finger millet is also rich in antioxidants, which have sort of become a byword in health books today. Antioxidants prevent excessive oxidation (how surprising!), which could otherwise cause cancer and ageing because of cell damage. The phenolic acids, flavonoids and tannins present in finger millet seed coats have very effective antioxidant properties. In general, it has been shown that people on millet-based diets have lower incidences of esophageal cancer than those on wheat or maize-diets. Ragi Keeps you Young: Aside from the phenolic content and antioxidants which are important factors in preventing ageing, finger millet and kodo millet have specifically shown potential in inhibiting cross-linking of collagen. Collagen cross-linking is the process by which cross-links form between or within collagen molecules in tendons, skin, and even blood vessels. Collagen is what gives tissues their elasticity, and cross-linking reduces this ability, leading to the stiffness commonly associated with age. Ragi Reduces "Bad" Cholestrol, Prevents Cardiovascular Disease: Emerging research has shown that finger millet has the potential to reduce risk of cardiovascular diseases. Technically speaking, finger millet reduces concentrations of serum triglycerides and inhibits lipid oxidation and LDL cholesterol oxidation. LDL (Low Density Lipoprotein) cholesterol is what is termed "bad" cholesterol and is especially troublesome when oxidized. Oxidized LDL inflames the arteries, leading to arteriosclerosis and the risk of heart attack or strokes.

Finger millet is an excellent source of natural calcium which helps in strengthening bones for growing children and aging people. Regular consumption of finger millet is good for bone health and keeps diseases such as osteoporosis at bay and could reduce risk of fracture. It is now established that phytates, polyphenols and tannins can contribute to antioxidant activity of the millet foods, which is an important factor in health, aging and metabolic diseases. Finger millet's phytochemicals help in slowing digestion process. This helps in controlling blood sugar level in condition of diabetes. It has been found that finger millet based diet helps diabetics as it contains higher fibre than rice and wheat. Also, the study found that diet based on whole finger millet has lower glycemic response i.e. lower ability to increase blood sugar level. This is due to presence of factors in finger millet flour which lower digestibility and absorption of starch. Because of its high nutritional content ragi flour is recommended as a weaning food especially in the southern parts of India. Finger millet is a very good source of natural Iron and its consumption helps in recovery of Anemia. The Ragi based foods are highly suited for expectant mothers and elderly due to their high calcium and iron content. Finger millet consumption helps in relaxing body naturally. It is beneficial in conditions of anxiety, depression and insomnia. It is also useful for migraines. Green ragi (finger millet) is recommended for conditions of blood pressure, liver disorders, asthma and heart weakness. Green ragi is also recommended to lactating mothers in condition of lack of milk production. If consumed regularly, finger millet could help in keeping malnutrition, degenerative diseases and premature aging at bay. So, finger millet is an extremely nutritious cereal and is very beneficial for maintaining a good health. Therefore have received attention for their potential role as functional foods. However, its high intake could increase quantity oxalic acid in the body. Therefore, it is not advised to patients having kidney stones (Urinary Calculi (Vikaspedia, 2023).

REFERENCES

Agritech. 2018. Ragi Expert System. http://www.agritech.tnau.ac.in/expert_system/ragi/index.html.

Agritech. 2023. Ragi - Eleusine coracana. http://www.agritech.tnau.ac.in/expert_system/ragi/botany.html

APEDA. 2023. International Year of Millets. https://apeda.gov.in/milletportal/Finger_Millet.html

Bhat, B.V., Rao, B.D. and Tonapi, V.A. 2018. The story of millets. Karnataka State Department of Agriculture, Bengaluru, India and ICAR-Indian Institute of Millets Research, Hyderabad, India

Byjus. 2023. Which state is the highest producer of Ragi in India?. https://byjus.com/question-answer/which-state-is-the-highest-producer-of-ragi-in-india-maharashtrakarnatak

Ceasar, S.A., ... Ignacimuthu, S., et al. 2023. Finger millet (Eleusine coracana (L.) Gaertn) In: Neglected and Underutilized Crops

Chandrashekar, A. 2010. Chapter 6 - Finger Millet: Eleusine coracana. In: Advances in Food and Nutrition Research, 59:215-262. DOI:10.1016/S1043-4526(10)59006-5

Das, S. 2020. Botany, Nutritional Facts & Cultivation Practices of Ragi. https://www.slideshare.net/ShovanDas15/botany-nutritional-facts-cultivation-practices-of-ragi

Das, S., Mishra, R.C., Rout, G.R. and Aparajita, S. 2007. Genetic variability and relationships among thirty genotypes of finger millet (*Eleusine coracana* L. Gaertn.) using RAPD markers. Z Naturforsch C J Biosci, 62(1-2):116-22. doi: 10.1515/znc-2007-1-220. PMID: 17425116.

de Wet, J. M. J., Prasada Rao, K. E. , Brink, D. E., Mengesha, M. H. 1984. Systematics and evolution of *Eleusine coracana* (Gramineae). Botany, 71(4): 550-557

Dodake, S. S. and Dhonukshe, B. L. 1998. Variability in Floral Structure and Floral Biology of Finger Millet (*Eleusine Coracana* (L.) Gaertn.). Indian Journal of Genetics and Plant Breeding, 58(01): 107–112 .

Eagri. 2022. *Eleusine coracana* Gaertn. http://eagri.org/eagri50/GPBR212/lec07.pdf

Eagri. 2023. Finger Millet. http://eagri.org/eagri50/GPBR212/lec07.pdf

Fuller, D.Q. 2006. Agricultural origins and frontiers in South Asia: a working synthesis. J World Prehist 20:1

Gupta, A., Sood, S., Agrawal, P.K. and Bhatt, J.C. 2011. Floral Biology and Pollination System in Small Millets. The European Journal of Plant Science and Biotechnology 6 (Special Issue 2): 80-86

Heuzé, V. and Tran, G. 2015. Finger millet (Eleusine coracana), grain. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/721 Last updated on May 11, 2015, 14:34

Hilu, K.W. and Johnson, J.L. 1992. Ribosomal DNA variation in finger millet and wild species of *Eleusine* (Poaceae). Theor Appl Genet 83:895–902

Hindavi. 2015. ragi | Hindavi, The Kitchens of Indian History. https://kitchensofhistory.wordpress.com/tag/ragi/

Indiabiodiversity. 2023. *Eleusine coracana* (L.) Gaertn. https://indiabiodiversity.org/species/show/229601

Isha. 2023. 7 Health Benefits of Ragi & 6 Easy Ragi Recipes. https://isha.sadhguru.org/in/en/blog/article/ragi-benefits-recipes

Joshi, R.P., Jain, A.K., Kumari, M., et al. 2021. Origin, domestication, and spread. In: (eds. Singh, Mohar and Sood, Salej) Millets and pseudo cereals : genetic resources and breeding advancement

Karki, A., Chandra, A., Joshi, S., Rawat, P. and Sharma, S. 2020. An overview of Finger millet (*Eleusine coracana* L.). Journal of Pharmacognosy and Phytochemistry, 9(4): 866-869

Knowled. 2023. In which region is ragi grown in India? Why?. https://www.knowledgeboat.com/question/in-which-region-is-ragi-grown-in-india-why--137116122240688220

Krishna, T. A., Maharajan, T., David, R. H. A., Ramakrishnan, M., Ceasar, S. A., Duraipandiyan, V., et al. 2018. Microsatellite markers of finger millet (*Eleusine coracana* (L.) Gaertn) and foxtail millet (*Setaria italica* (L.) Beauv) provide resources for cross-genome transferability and genetic diversity analyses in other millets. Biocatal. Agric. Biotechnol. 16, 493–501. doi: 10.1016/j.bcab.2018.09.009

Krishna, T. A., Maharajan, T., Roch, G. V., Ramakrishnan, M., Ceasar, S. A., and Ignacimuthu, S. 2020. Hybridization and hybrid detection through molecular markers in finger millet [*Eleusine coracana* (L.) Gaertn.]. J. Crop Improv. 34, 335–355. doi: 10.1080/15427528.2019.1709596

Kumar, B.S.S. 2017. A hardy millet yields its genetic code. The Hindu. 7 July 2017. https://www.thehindu.com/sci-tech/agriculture/ragi-yields-its-genetic-code/article19235611.ece

Kumar, A., Metwal, M., Kaur, S., Gupta, A. K., Puranik, S., Singh, S., et al. 2016. Nutraceutical value of finger millet [*Eleusine coracana* (L.) Gaertn.], and their improvement using omics approaches. Front. Plant Sci. 7: 934. doi: 10.3389/fpls.2016.00934

Lakshmanaiah, C.H. 1967. High yielding varieties of irrigated ragi. In: Proceedings of state level symposium on high yielding varieties. Administrative Training Institute, Mysore, India

Lovisolo, M.R. and Galati, B.G. 2007. Ultrastructure and development of the megagametophyte in *Eleusine tristachya* (Lam.) Lam. (Poaceae). Flora 202:293–301

Maharajan, T., Ceasar, S.A., Krishna, T.P.A. and Ignacimuthu, S. 2021. Finger Millet [*Eleusine coracana* (L.) Gaertn]: An Orphan Crop With a Potential to Alleviate the Calcium Deficiency in the Semi-arid Tropics of Asia and Africa. Front. Sustain. Food Syst., 5. https://doi.org/10.3389/fsufs.2021.684447

Mercer, K.L. and Perales, H.R. 2010. Evolutionary response of landraces to climate change in centers ofcrop diversity. Evol Appl 3:480–493
Millets. 2023. Salient features of released varieties of finger millet crops. https://millets.res.in/technologies/finger_millets_varieties.pdf
Mirza, N. and Marla, S.S. 2020. Finger Millet (*Eleusine coracana* L. Gartn.)Breeding. https://www.researchgate.net/publication/336439015
POWO. 2023. Eleusine coracana (L.) Gaertn. Fruct. Sem. Pl. 1: 8 https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:399945-1
Prabhu, K.S., Das, A.B. and Dikshit, N. 2018. Assessment of genetic diversity in ragi [*Eleusine coracana* (L.) Gaertn] using morphological, RAPD and SSR markers. Z Naturforsch C J Biosci, 73(5-6):165-176. doi: 10.1515/znc-2017-0182. PMID: 29654693.
Pravina, P., Sayaji, D., and Avinash, M. (2013). Calcium and its role in human body. Int. J. Res. Pharm. Biomed. Sci. 4, 659–668.
Rachic, K.O. and Peter, L.R.V. 1977. The *Eleusines* (A Review of the World Literature). International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad
Sonnad, S.K., Shanthakumar, G. and Salimath, P.M. 2008. Genetic Variability and Character Association Studies in White Ragi (*Eleusine coracana* Gaertn). Karnataka J. Agric. Sci., 21(4) (572-575): 2008
Toppr . 2023. Which state of India is the leading producer of ragi?. https://www.toppr.com/ask/question/which-state-of-india-is-the-leading-producer-of-ragi/
Toshi, N. 2023. Ragi (Finger Millet): Health Benefits And Tasty Recipes For Losing Weight. https://pharmeasy.in/blog/ragi-health-benefits-and-tasty-recipes-for-losing-weight/
Tadele, Z. 2019. Orphan crops: their importance and the urgency of improvement. Planta 250, 677–694. doi: 10.1007/s00425-019-03210-6
Upadhyaya, H.D., Sarma, N.D.R.K., Ravishankar, C.R., et al. 2010. Developing a mini-core collection in finger millet using multi-location data. Crop Sci 50(5):1924–1931
Valke, D. 2023. *Eleusine coracana* (L.) Gaertn. https://www.flickr.com/photos/dinesh_valke/2934263357
Vetriventhan, M., ... Shailesh Kumar Singh. 2016. 7 - Finger and foxtail millets. In: (eds. Mohar Singh and Hari D. Upadhyaya) Genetic and Genomic Resources for Grain Cereals Improvement. Pp 291-319.
Vijaykumar, V. 2021. The Unmissable Benefits & Uses of Ragi For Health. The New Indian Express,Chennai. 5.5.2021
Vikaspedia. 2020. Finger Millet (Ragi) - Small seeds with bigger health benefits. https://vikaspedia.in/health/nutrition/nutritive-value-of-foods/nutritive-value-of-cereals-and-millets/finger-
Vikaspedia. 2023. Finger Millet (Ragi) - Small seeds with bigger health benefits. https://www.vikaspedia.in/health/nutrition/nutritive-value-of-foods/nutritive-value-of-cereals-and-millets/finger-millet-ragi-small-seeds-with-bigger-health-
Wambi, W., Otienno, G., Tumwesigye, W., and Mulumba, J. 2020. Genetic and genomic resources for finger millet improvement: opportunities for advancing climate-smart agriculture. J. Crop Improv. 35, 204–233. doi: 10.1080/15427528.2020.1808133
Wariar, U.A. and Divakaran, K. 1956. A high-yielding white-grained ragi. Madras Agric. J 43:73–76
WebMDEC. 2022. Health Benefits of Finger Millet. https://www.webmd.com/diet/health-benefits-finger-millet
Wikipedia. 2023. *Eleusine coracana*. From Wikipedia, the free encyclopedia. https://en.wikipedia.org/wiki/Eleusine_coracana
Wikipedia. 2023a. *Eleusine coracana* Gaertn. English Wikipedia - Species Pages. https://www.gbif.org/species/113643435

****