

## Chapter

# Finger Millet Scientific Cultivation and Its Uses in India

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## Abstract

Finger millet (*Eleusine coracana* L.) is a prevalent grain crop in the dry parts of Asia and Africa. It prolongs to be a staple food and is known locally as “Ragi” in southern states like Karnataka, Andhra Pradesh, and Telangana, especially in Karnataka. It serves as fodder as well as grain. Its grain is the richest source of calcium and it is utilized in a wide range of food products, including cakes, puddings, sweets, and other baked products. There are many homemade products prepared with finger millet and some of the well-known products are ragi roti, ragi dosa, ragi balls, ragi porridge, ragi upma, ragi cakes, and ragi biscuits. In addition, it is used to manufacture beer and liquor (known as arake or areki in Ethiopia), and also its different products are fed to animals. Due to its high fiber, mineral, vitamin, macro and micro-nutrient, phytochemicals contents, and its endowing ability to fight off chronic diseases. A cheap, satisfying, and healthful diet can be made by including finger millet in a regular diet.

**Keywords:** finger millet, cultivation, nutritional importance, quality, uses

## 1. Introduction

Finger millet (*Eleusine coracana*) is a domesticated crop of African origin and it is spread throughout the world. It is also known as korakan, ragi, or dagusa in India. Even though the wild progenitor species (*Eleusine africana*) is well recognized, this species was first domesticated in Africa [1]. Ecologically, it is thought to originate from a highland region as a crop and is frequently planted in hilly regions [2]. The crop is grown in a wide range of challenging environmental situations. Finger millet blessing for vast arid and semi-arid regions because it can be cultivated on low-fertility soils [3]. Finger millet is clearly regarded as a staple food and it is used as animal feed (straw) in industrialized countries and as food (grains) in underdeveloped [4]. It is a major crop of semi-arid and arid regions and developing nations of Asia and Africa [5]. Finger millet is the fourth most produced millet in the world, behind sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), and foxtail millet (*Setaria italica*) [6]. Millet grains are rich in vitamins,

iron, carbohydrates, calcium (Ca), potassium, zinc, phosphorus, magnesium, and vital amino acids, they are also nutritionally superior to rice and wheat [7]. The seed coat (testa), embryo, and endosperm are the three primary components of the finger millet grain. Finger millet grain are red, yellow, white, tan, red, brown, and violet, in color and this type of variety grown around the world. It is compared to other millets including foxtail millet, pearl millet, Kodo millet, and proso millet, finger millet distinctive due to the existence of five layered testa. This might be one of the reasons why finger millet has a greater level of dietary fiber [8]. Finger millet's ability to withstand droughts may be linked to its high antioxidant content. In underdeveloped countries, there is huge potential for millet grains to be transformed into foods and beverages with additional value [9].

## 2. Nutritional importance of finger millet

Next to fine cereal grains [10] and gluten-free cereal goods [7], finger millets are a prominent diet in Asia and Africa's resource-poor nations since they account for 75% of total caloric consumption. Because of the high amount of dietary fiber, iron, zinc, calcium, phosphorus, potassium, vitamin B, and essential amino acids, it is nutritionally superior to wheat and rice [11, 12]. In comparison to other millets, finger millet has higher levels of lysine, threonine, and valine [13, 14]. It contains some of the anti-nutrients *viz.*, Phytates, polyphenols, tannins, trypsin dietary fiber, and inhibitory substances. Dietary fiber and polyphenols in finger millet have a number of health advantages, including actions that are anti-diabetic, antioxidant, hypocholesterolemic, anti-microbial, delay nutrient absorption, raise fecal bulk, and lower blood lipid levels [15]. It was discovered that finger millet contains more than 50 phenolic compounds from a variety of groups, including phenolic acids and their derivatives, dehydrodiferulates, dehydrotriferulates, flavan-3-ol monomers and dimers, flavonols, flavones, and flavanonols [7]. Furthermore, finger millet is helpful in managing a number of physiological conditions, including diabetes mellitus, hypertension, vascular fragility, hypercholesterolemia, and the prevention of low-density lipoprotein (LDL) oxidation [16]. The risk of cardiovascular diseases, type II diabetes, gastrointestinal malignancies, and other health problems can be reduced by consuming finger millet and its products on a daily basis [17].

## 3. Status area and production

The majority of finger millet is grown in semi-arid tropical regions of Asia and Africa. The southern states of India are where finger millet is primarily grown in Asia, and these regions have ideal growing conditions. Finger millet is the fourth most produced millet in the world after sorghum, pearl millet (*Cenchrus americanus*), and foxtail millet (*Setaria italica*). India produces 1.70 million tonnes of finger millet, which is grown over 1.07 million hectares' area [18]. The states Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Telangana, Uttarakhand, Jharkhand, Madhya Pradesh, and Haryana are important producers of finger millet. In addition to being utilized for direct human consumption, finger millet has a

wide range of other uses, including animal feed, distilleries, and food processing for value-added goods [19].

## 4. Seed and sowing methods

### 4.1 Land preparation

One deep plowing is advised with a mold-board plow in the months of April or May. Before sowing, smooth seedbed preparation with secondary tillage using a cultivator and multiple tooth hoe is required. Therefore, appropriate seed and land preparation aid in better germination, reduce weed issues and effectively save soil moisture. Small seeds take about 5–7 days to germinate. In Uttaranchal, where it is difficult to carry out frequent plowing operations, efficient soil turning and digging, weed removal from perennial plants, land smoothening, and the provision of an inward slope with a shallow drain all help in draining surplus rainwater [20].

### 4.2 Seed rate and sowing

The recommended seed rate for sowing a one-hectare field is 8–10 kg of seed and 4–5 kg of seed sufficient for transplanting. To avoid infections, seeds should be treated with Thiram @ 2.5 g/kg of seeds. The best time for sowing is between June and July for the *Kharif* and September and October for the rabi. Usually, crops are grown during the *Kharif* season. In some areas, the crop is cultivated in irrigated conditions during the rabi season.

The line sowing is advantageous because it promotes inter-cultivation and provides efficient weed control and sowing with a seed drill and keeping space 22.5–30.0 cm between rows and 7.5–10.0 cm between plants, it is help in to maintain an ideal plant population of 4–5 lakh/ha (**Tables 1** and **2**) [20, 21].

| Name of the state                                                                | Sowing duration                           |
|----------------------------------------------------------------------------------|-------------------------------------------|
| Andhra Pradesh                                                                   | Early <i>kharif</i> (May–August)          |
|                                                                                  | Late <i>kharif</i> (July–November)        |
|                                                                                  | Late Rabi (November–March)                |
| Bihar, Jharkhand, Gujarat, Himachal Pradesh, Uttar Pradesh, Uttara Khand, Orissa | <i>Kharif</i> (June–September)            |
| Karnataka, Tamil Nadu                                                            | Kar or Early <i>Kharif</i> (April–August) |
|                                                                                  | <i>Kharif</i> (July–November)             |
|                                                                                  | Rabi (October–September)                  |
|                                                                                  | Summer (January–May)                      |

**Table 1.**  
*Finger millet is grown in all the cropping seasons in different parts of the country.*

## 5. Cropping systems

| State                                    | Systems                                                                                     |
|------------------------------------------|---------------------------------------------------------------------------------------------|
| Karnataka, Tamil Nadu and Andhra Pradesh | Finger millet + pigeon pea (8–10:2)                                                         |
|                                          | Finger millet + filed bean (8:1)                                                            |
|                                          | Finger millet + soybean (4:1)                                                               |
| Bihar                                    | Finger millet + pigeon pea (6:2)                                                            |
| Uttaranchal                              | Finger millet and soybean mixed together in 90:10 per cent proportion by weight basis       |
| North hilly areas                        | Finger millet + soybean in <i>Kharif</i> and oats in rabi is an ideal remunerative sequence |
| Maharashtra (Kolhapur)                   | Finger millet + black gram/moong bean (6–8: 1) (Sub montane regions)                        |

**Table 2.**

*Intercropping systems of finger millet growing in different regions and states of India [20, 21].*

## 6. Nutrient management

The application of farm yard manure before sowing of the crop is 5–10 t/ha. Fertilizer applications give better results to produce a higher yield. Fertilizer recommendations for finger millet are 40 kg nitrogen (N), 20 kg phosphorus (P), and 20 kg potassium (K) per ha for rainfed cultivation and 60 kg N, 30 kg P, and 30 kg K per ha for irrigation. Rao et al. [22] found that application rates of up to 40 kg N/ha of nitrogen fertilizer resulted in improved grain yield and protein content in finger millet. According to Hedge and Gowda [23] found that the application rate of phosphorus was increased from 30 to 60 kg/ha phosphorus to improve grain yield. The application of zinc (Zn), boron (B), and sulfur (S) coupled with N, P increased the yield of finger millet grains (56%), Stover biomass (44%), total biomass (48%), and plant uptake of Zn (66%) and B (22%) compared to the addition of N and P alone, according to Srinivasarao et al. [24]. Rao et al. [25] reported that the application of B and Zn along with N, P, and S fertilizer increased finger millet's grain, straw yield, and nutrient uptake of N, P, S, B, and Zn. Finger millet treated with *Azospirillum* + *arbuscular mycorrhizal* (AM) fungi + PSB improved plant growth and N, P uptake [26]. When finger millet was treated with AM fungus in comparison to uninoculated plants the absorption of macronutrients (N, P) and micronutrients (Zn, Cu) was improved in plants [27].

The application of *Azotobacter* and PSB coupled with fertilizer (based on soil testing) and FYM (10 t/ha) enhanced finger millet yield in comparison to the recommended fertilizer treatment alone [28].

## 7. Water management

Finger millet cultivated in rainfed conditions does not require any irrigation, but if rain delays for a long period of time between tillering and flowering stages, irrigation should be necessary to produce a reasonable yield. To fulfill the water requirement of crops to create furrows and ridges for irrigation [29]. Because the

crop cannot thrive in wet conditions, it is very crucial to remove excess water after rain. Since it is a drought-tolerant crop, additional watering at critical stages of the growth cycle results in a good yield from finger millet-based farming systems [30]. If we want to get a good yield from a finger millet-based cropping system in a drought-prone area, drip irrigation is an alternate and efficient technique of irrigation. Other management techniques, including as mulching, intercropping, growing pulses in intercropping, Intercultivation, and application of organic manure, boost soil moisture retention and increase the yield of finger millet-based cropping systems. Finger millet and pulse intercropping also reduce soil erosion and the loss of nutrients from the top fertile soil. According to Jagadeesha [31], sewage sludge treatment results in maximum moisture retention and the most efficient use of water. Studies show that using organic manure can improve water retention and effective rainfall, both of which serve to increase production when there is a water shortage.

| Weed species                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | States in which it was reported as a major weed                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| <i>Cyperus rotundus</i> , <i>Cynodon dactylon</i> , <i>Commelina benghalensis</i> , <i>Ageratum conyzoides</i> , <i>Echinochloa colona</i> , <i>Dactyloctenium aegyptium</i> , <i>Digitaria marginata</i> , <i>Eleusine indica</i> , <i>Spilanthus acmella</i> , <i>Acanthospermum hispidum</i> , <i>Eragrostis pilosa</i> , <i>Celosia argentea</i> , <i>Parthenium hysterophorus</i> , <i>Amaranthus viridis</i> , <i>Euphorbia hirta</i> , <i>Alternanthera sessilis</i> , <i>Digitaria sanguinalis</i> (L.) Scop., <i>Leucas aspera</i> , <i>Sida accuta</i> Burm. f. | Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Orissa, Karnataka, Tamil Nadu, West Bengal, Uttar Pradesh, |

**Table 3.**  
Major weeds associated with finger millet in India [32].

| Sr. N. | Management                                                                                                                                                                              | Location state                                       | References |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------|
| 1.     | The conventional tillage (plowing twice + harrowing once + inter-cultivation twice at 25 and 50 days after sowing (DAS) in Alfisols when compared to minimum and zero tillage practices | Bangalore, Karnataka                                 | [33]       |
| 2.     | Hoeing twice by wheel hoe between rows + intra-row manual weeding <i>fb</i> HW twice 20 and 40 DAS                                                                                      | Raipur, Chhattisgarh                                 | [34]       |
|        | 2, 4-D sodium salt 0.75 kg/ha post-emergence application (PoE) 15–20 DAS                                                                                                                | Bangalore, Karnataka; Berhampur, Orissa              | [35, 36]   |
| 3.     | Bensulfuron-methyl (0.6% G) + pretilachlor (6.0% G) 0.75 kg/ha (ready-mix) pre-emergence application (PE) (3 DAS)                                                                       | Bangalore, Karnataka                                 | [37, 38]   |
| 4.     | Oxyfluorfen 0.1 kg/ha PE <i>fb</i> HW once 20 DAP<br>Oxyfluorfen 0.1 kg/haPE                                                                                                            | Tirupati, Andhra Pradesh<br>Mandya, Karnataka, India | [39, 40]   |
| 5.     | Bensulfuron-methyl 60 g + pretilachlor 600 g (6.6% G pre-mix formulation) 1.0 kg/ha pre-emergence application (PE) 2 DAP                                                                | Mandya, Karnataka                                    | [41]       |

**Table 4.**  
Method of weed control.

## 8. Weed management

Finger millet adapts well in adverse environmental conditions. Weed associated with finger millet is also adapted to those unfavourable conditions to compete with finger millet for the limited resources. Hence, it is essential to understand the ecology of weeds associated with finger millet to manage them properly (Tables 3 and 4) [42].

When finger millet is exposed to harsh environmental conditions, it adapts well and rapidly. In order to finger millet, compete with weeds for the resources and weed affects the overall development of the crop. Therefore, in order to effectively control of weeds associated with finger millet is crucial to understand their ecology [42]. The proper control of weeds increases finger millet yields. Integrated weed management (IWM) in the combination of herbicides, mechanical weeding methods, and hand weeding techniques successfully controlled the weeds in finger millet crop. IWM efficiently controls the losses caused by weeds like lowers nutrient uptake, which makes nutrients available to finger millet and lowers the cost of applying surplus fertilizers [43].

| Sr. N. | Name of insect                                          | Damaging symptoms                                                                                                                                                                          | Management                                                                                                                                                                                                                                                                                                                 |
|--------|---------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.     | Cutworms<br>( <i>Spodoptera exigua</i> )                | The caterpillars cut seedlings at the base during early stage, which appears as if grazed by domestic animal. They are active during night and hide under stones and clods during the day. | After harvesting of crop remove weeds from the fields. Spray Quinalphos 20 EC @ 2 l/ha, Carbaryl 50 WP @ 2.5 kg/ha, or Phosalone 35 EC @ 1.25 l/ha. Apply the biological agent's like- <i>entomopathogenic</i> nematode <i>Steinernema carpocapsae</i> or the fungus <i>Beauveria bassiana</i> when cutworms first emerge. |
| 2.     | Pink stem borer ( <i>Sesamia inferens</i> )             | Pink larva enters into the stem and causes dead heart symptoms.                                                                                                                            | Spray cartop hydrochloride 4G @ 25 kg/ha, fipronil 0.3G 15kg chlorpyrifos 10G 10kg in whorls.                                                                                                                                                                                                                              |
| 3.     | Aphids<br>( <i>Rhopalosiphum maidis</i> )               | The Aphid Colonies present on the central leaf whorl and ears and after that yellowing of leaves. The appearance of ants at the infected plant parts.                                      | Spray any one of the following insecticides mixed in 10 l of water using a high-volume sprayer if dusting is not done: Methyl demeton 25 4EC 20 ml/ha Dimethoate 30 EC 20 ml/ha                                                                                                                                            |
| 4.     | White Grub,<br><i>Holotrichia consanguinea</i>          | Grubs feed on roots which results in the death of the grown-up plants.                                                                                                                     | After the summer rains, initiate a widespread operation to collect and eliminate adult beetles that are hiding out in in the field. Use <i>Beauveria brongniortii</i> @ 2.5 kg/ha (1*10 <sup>9</sup> cfu/g) <i>entomopathogenic</i> fungal formulation combined with FYM.                                                  |
| 5.     | Earhead caterpillars<br>( <i>Sitotroga cerealella</i> ) | Earhead caterpillars appear at the dough stage on ears and persist till harvest. The caterpillars bite the maturing seeds and make a fine web out of their casting and half-eaten grains.  | Dust Malathion 5% @ 24 kg/ha or Quinalphos 1.5% @ 24 kg/ha.                                                                                                                                                                                                                                                                |

**Table 5.**  
Insects and their management [44, 45].

| Sr. N. | Name of diseases                                                            | Damaging symptoms                                                                                                                                                                                                                                                                                                           | Management                                                                                                                                                                                                                                                                                                           |
|--------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.     | Blast ( <i>Pyricularia grisea</i> )                                         | Young seedlings are infected in the nursery and in the fields, with spindle-shaped lesions of various sizes. Typical blast lesions are diamond shaped with a gray center and dark margin appearing on the leaf. The lesions are like those on the seedlings and are about 0.3–1.0 cm in breadth and about 1–2 cm in length. | The cultivation of resistant varieties can manage it. A day before planting, treat the seeds with fungicides such carbendazim @ 2 g/kg seed. Spray Tricyclazole (0.1%) or Carbendazim (0.1%) in the nursery if necessary. Use any of the fungicides suggested above at the flowering stage and repeat 10 days later. |
| 2.     | Leaf spot ( <i>Helminthosporium nodulosum</i> )                             | Progressive infection from older to younger leaves can be observed in the standing crop. The leaf, leaf sheath, other plant parts are affected and shows small to medium-sized brown to dark spots.                                                                                                                         | The disease can be effectively managed by proper nutrition and water management. Need-based spraying of <i>Mancozeb</i> (0.2%) can be applied. However, field sanitation and spraying of Carbendazim at the rate of 0.05% has been reported to reduce infection to some extent.                                      |
| 3.     | Downy Mildew or Green Ear Disease ( <i>Sclerophthora macrospora</i> )       | The plant assumes a bunchy and bushy appearance. Often, pale yellow translucent spots are seen on the leaves of affected plants. The white cottony growth, characteristics of many downy mildews, is generally not seen in the downy mildew of finger millet.                                                               | Affected plants should be destroyed by burning. Keep the field clean. In case of severe attack spray Mancozeb on the standing crop at the rate of 2 g/l of water.                                                                                                                                                    |
| 4.     | Bacterial Leaf Spot ( <i>Xanthomonas campestris</i> pv. <i>Eleusineae</i> ) | The typical symptom appears as light yellowish to brown dots on the leaf's both surfaces. They extend along the veins in a linear pattern. Subsequently, the color turns dark brown, and as the illness worsens, the leaf blade splits along the streaks.                                                                   | The spray of mancozeb @ 2 g/l or copper oxychloride @ 2.5 g/l. Seed treatment with 0.1% mercuric chloride solution for 2–5 minutes is effective. Spraying with streptomycin should not be done after fruits begin to form. Field sanitation is important. Also, seeds must be obtained from disease-free plants.     |

**Table 6.**  
*Diseases and their management.*

## 9. Plant protection

### 9.1 Insect pests and their management

Finger millet attracts several pests of which armyworms, cutworms, stem borers, leaf aphids, grasshoppers, gray weevils, shoot flies, and ear caterpillars are major ones (Tables 5 and 6).

## 10. Harvesting and post-harvest management

When millet grains reach full physical maturity, they should be harvested. Due to quick temperature and humidity changes, late harvesting could result in losses and

grain quality deterioration. Millet can be threshed manually or mechanically, including by pounding the panicles with sticks. When the crop is harvested by hand, the panicle is separated from the upright stalk at a moisture level of approximately 16–20%, and the stalks are used as animal feed. Before threshing, the grain's dryness can be determined by biting into it with the teeth or pinching it between the fingers. A dry glass bottle is filled with dry salt, the grain is added, and the bottle is shaken to test the salt. If, after a few minutes, the salt adheres to the bottle's sides, the grain's moisture content is above 15%; if not, the grain's moisture content is correct. Using the teeth (the grains are brittle when bitten) or pinching with the fingers, one can determine the dryness of the grain prior to threshing [29]. The grain must be dried once more to a moisture content of 13% or less after it has been threshed. The threshed grain should be dried on wire mesh trays, mats, sheets, or tarpaulins made of plastic that have been elevated on a platform. To allow air to travel through the grain while it dries, spread it out thin on the drying surface. Be sure to move the grain frequently to prevent overheating. Keep the grain dry and free from dirt, insects, animals, and rain [46, 47].

## **11. Utilization of finger millet**

Even though finger millets have a wide variety and excellent nutritional content. The start-up movement of finger millet to increase the availability of nutrient-rich food has recently been steadily fuelled by these grains [48]. Tribal people save 75% of their finger millet harvest for food, therefore eating it every day is a ritual. The availability of finger millet is found to be practically year-round in their homes 65% of households, but we still need to address the remaining 35% of families to ensure year-round availability. Most families believe they eat finger millet because it provides more energy than other foods and makes it easy to carry out daily tasks, and they are least likely to be aware of blood sugar regulation [49]. Processing may be two different types: main processing and secondary processing. Primary processing consists of operations like cleaning, washing (soaking/germination), dehulling, milling (into flour and semolina), and removing the undesirable seed coat and anti-nutritional factors, while secondary processing entails transforming raw materials into “ready-to-cook” (RTC) or “ready-to-eat” (RTE) products through flaking, popping, extrusion, and baking [50]. In India, malting finger millet is a common practice that produces ragi malt and a milk thickening practice that is used in baby food and other products. The preparation of products made only of millet and the mixing of millet with other ingredients can be done using a variety of techniques. These techniques can be similar to those used to prepare products from wheat and rice or they can differ because finger millets have different physical-chemical characteristics than the other cereal grains. The grain is also malted, and the flour produced from the malted grain is used to feed newborns and the elderly [51]. The development of a pleasant aroma during the kilning of the germinated grain is an additional benefit of malting ragi. In order to make milk drinks, malted ragi flour, also known as “ragi malt,” is utilized. In certain regions of the nation, a fermented beverage called beer is also made from grain [7, 52].

## **12. Conclusion**

This crop is perfect for dry land farming because of its strong ability for regeneration after the relief of stressful circumstances. The major states in India where

finger millet is grown include Karnataka, Uttarakhand, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand, and Maharashtra. Furthermore, finger millet is a crucial component of dietary and nutritionally balanced diets since it is equally rich in carbohydrates, energy, and nutrients. Despite the fact that finger millet is a very healthy grain with a high nutritional value, a high consumption may cause the body to produce more oxalic acid. Compared to other cereals, millets are nutritionally dense, and processing and employing millets in the production of products has undeniable potential in terms of health benefits, nutrition, and quality. By increasing the digestibility of the protein and the bioavailability of the minerals, simple processing methods like soaking, germination/malting, and fermentation may assist address the issue of protein-energy deficiency. In order to increase consumer acceptance of small millets without sacrificing their health advantages, processing procedures for these grains still need to be optimized. Additionally, knowledge must be raised about the effects of processing techniques on millets' nutritional qualities and health advantages at both the commercial and household levels in order to address food poverty and malnutrition.

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