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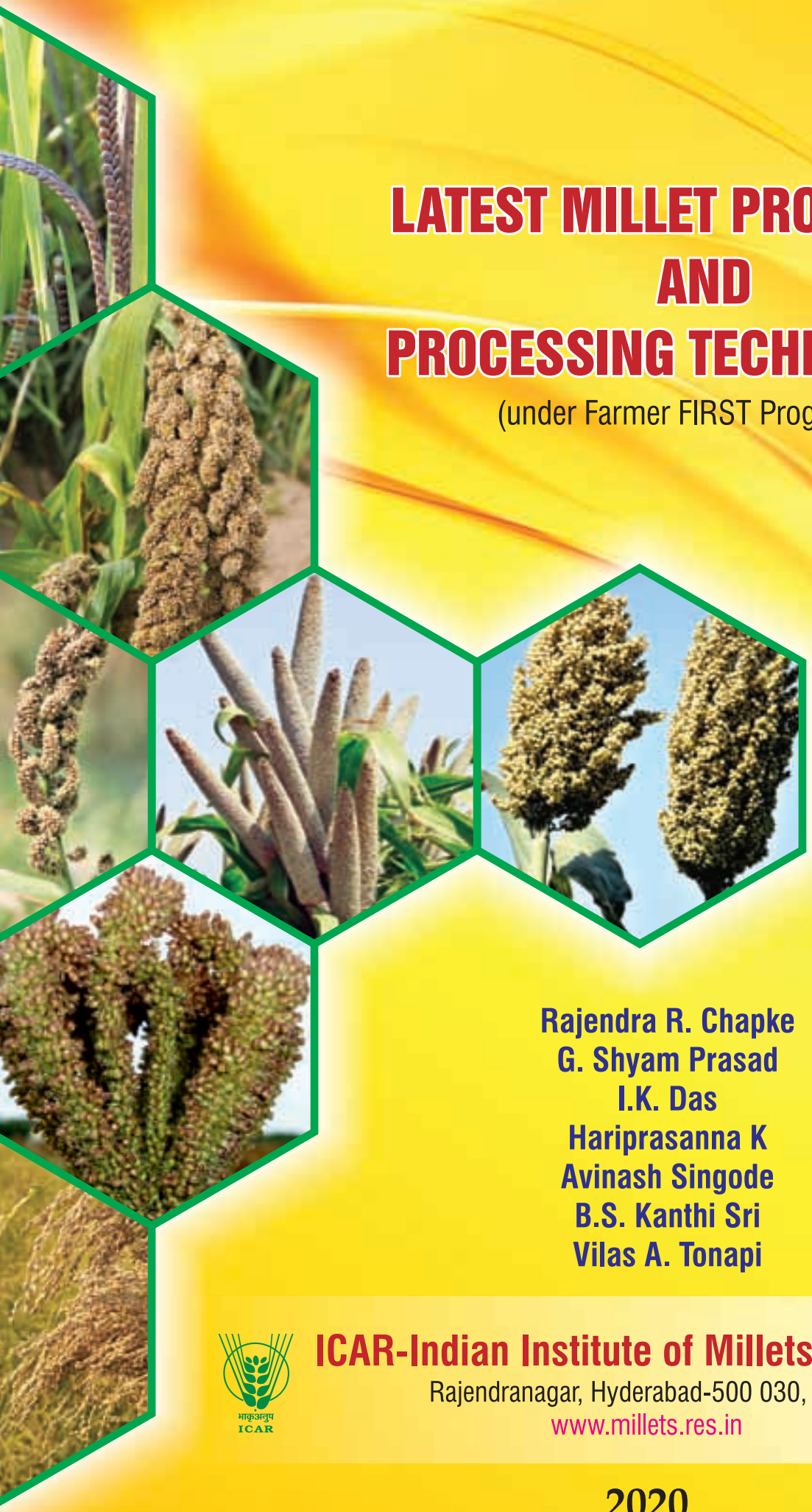

LATEST MILLET PRODUCTION AND PROCESSING TECHNOLOGIES

(under Farmer FIRST Programme)

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2020

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Abstract:

This booklet is a compilation of research-based recommendations and cultivation practices developed by ICAR-IIMR and ICAR-AICRPs on nine different millets including sorghum, suitable for different agro-climatic situations. The primary and secondary processing technologies of millets are also included for the benefit of the users. It will serve as a reference manual on improved millets production and processing technologies to millet growers, processing industries, extension functionaries and policy makers.

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- Authors

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1. Rainy (*kharif*) sorghum

(Sorghum bicolor (L.) Moench)

Common name: Jowar (Hindi), Great millet
Vernacular names: *Jwari* (Marathi), *Juar* (Bengali, Gujarati), *Jola* (Kannada), *Cholam* (Malayalam, Tamil), *Janha* (Oriya), *Jonnalu* (Telugu), Other names: *Milo, Chari*

Climate

Sorghum fits very well in a sustainable agricultural model with its ability to survive in water limiting conditions and provides an option for marginal farmers. It requires warm conditions but it can be grown under a wide range of climate. It is also widely grown in temperate regions and at altitudes of up to 2300 m in the tropics. It can tolerate high temperature throughout its life cycle better than any other crop. Sorghum requires about 26-30 °C temperature for good growth.

Soil

Grain sorghum can be grown on many different soils. Sorghum will yield best in deep, fertile, well-drained loamy soils. Nevertheless it performs well in shallow soils and drought conditions.

Usage

It is grown to meet the need of fodder and feed for animals and poultry in dryland rain-fed areas besides food grain. It is also used for industrial purposes such as bio-fuel, potable alcohol, starch, alternate food products, etc. It is a major source of nutrition and provides nutritional and livelihood security to the resource poor population in dryland agricultural areas.

1. Latest high yielding cultivars

Region / state	Hybrids	Recommended varieties
Maharashtra	SPH 1635, SPH 1641, CSH 41, CSH 35, CSH 30, CSH 25, CSH 16	PDKV Kalyani (AKSV -181), CSV39, CSV36, CSV 34, Palamuru jonna (CSV31), CSV 27, CSV20
Karnataka	CSH 41, CSH 35, CSH 30, CSH 18, CSH 17, CSH 16, CSH 14, CSH 13	CSV 36, CSV 34, Palamuru jonna (CSV31), CSV 27, CSV 17, CSV 15
Andhra Pradesh & Telangana	CSH 41, CSH 35, CSH 30, CSH 25, CSH 14	Palamuru jonna (CSV 31), CSV 39, CSV 36, CSV 27, CSV 23, CSV 20, CSV 17, CSV 15

Region / state	Hybrids	Recommended varieties
Madhya Pradesh	CSH 41, CSH 25, CSH 23, CSH 18, CSH 17, CSH 16	Raj Vijay Jowar 1862 (RVJ 1862), CSV 34, CSV 15, CSV 17, JJ 741, JJ 938, Palamuru jonna (CSV31)
Gujarat	CSH 41, CSH 35, CSH 27, CSH 25, CSH 18, CSH 16, CSH 13	GJ42 (SR-666-1), Palamuru jonna (CSV 31), CSV 39, CSV 36, CSV 34, CSV 17, CSV 15, GJ 41, GJ 40, GJ 39, GJ 38
Rajasthan	CSH 41, CSH 35, CSH 27, CSH 23, CSH 18, CSH 16, CSH 14	Palamuru jonna (CSV 31), CSV39, CSV36, CSV 23, CSV 20, CSV 17
Tamilnadu	CSH 41, CSH 35, CSH 27, CSH 18, CSH 17, CSH 16, CSH 14	K-12, Palamuru jonna (CSV 31), CSV 27, CSV 23, CSV 20, CSV 17, CO 26
Uttar Pradesh	CSH 27, CSH 25, CSH 23, CSH 18, CSH 16, CSH 14	CSV39, CSV36, Palamuru jonna (CSV31), CSV 23, CSV 20, CSV 17, CSV 15

Improved cultivation practices

1. Land preparation

Ploughing is required once in summer followed by 2-3 harrowings. Thereafter, around 8-10 tonnes of farm yard mannure (FYM) per ha need to be incorporated. Soil application of Phorate or Thimate @ 8-10 kg/ha is recommended at the time of sowing.

2. Sowing time

Suitable time for sowing is 3rd week of June to 1st week of July with onset of monsoon.

3. Seed rate

Optimum seed rate is 7-8 kg/ha or 3 kg/acre.

4. Spacing

Recommended row to row distance is 45 cm and plant to plant distance is 12 to15 cm within the row. Maintain plant population at 72,000 plants per acre (18 plants/ square meter).

5. Seed treatment

Treat the seed with 5 gm Imidacloprid 70 WS + 2 g Carbendazim (*Bavistin*) per kg of sorghum seed, or Thiomethoxam 3 gm/kg of seed. Seed treatment is essential to avoid major insect pest infestation and soil borne diseases.

6. Fertilizers application

Fertilizers must be used on the basis of soil type as mentioned below.

For light soils and low rainfall areas: Apply 30 kg N, 30 kg P_2O_5 and 20 kg K_2O per ha at the time of sowing. Apply another 30 kg N at 30-35 days after sowing (DAS).

For medium-deep soils and moderate to high rainfall areas: Apply 40 kg N, 40 kg P_2O_5 and 40 kg K_2O per ha at the time of sowing. Apply another 40 kg N at 30 DAS.

7. Weed control and inter cultivation

Keep the crop free from weeds at initial growth stage for about 35 days. Spray atrazine @ 0.5 kg a.i./ha immediately after sowing within 48 h to control weeds. One hand weeding at 20 DAS and inter-cultivation two times at 21 and 40 DAS should be done. Striga can be controlled by hand pulling when population is less, otherwise spray sodium salt of 2,4-D@ 1.0 kg a.i./ha, if infested. Two times inter-cultivation with blade hoe at 3 and 5 weeks after germination, will help to keep good soil aeration, control weeds and conserve moisture.

Intercropping

Sorghum intercropped with pigeonpea, green gram, soybean and sunflower are found beneficial and recommended. Sorghum and pigeonpea are to be sown in 2:1 row ratio without additional fertilizers. Medium to short duration sorghum genotypes like CSH 16, CSH 25 and CSH 35 are suitable. In intercropping, spraying of weedicide/ herbicide is not recommended. Sorghum and fodder cowpea in 2:2 row ratio provides green fodder, helps to improve soil fertility and check weed growth.

Sequence cropping

After *kharif* sorghum, a sequence crop like, chickpea, safflower and mustard during *rabi* season are found more suitable in most of the situations. These sequence cropping are found more profitable in areas which receive rainfall above 700 mm and having good moisture retention capacity like medium to deep black soils.

Major insect pests

1. Shoot fly

Shoot fly eggs

Shoot fly larvae

Adult

Dead heart symptom

It is a major pest of the sorghum and infestation occurs during seedling stage up to one month. Maggot cut the growing point and feeds on the decaying tissues. The infestation results in withering and drying of the central leaf, giving a typical "dead-heart" symptom.

Control measures

It can be managed by early sowing within 7 to 10 days of the onset of monsoon and using high seed rate @ 10 to 12 kg/ha in case of delayed sowing. Intercropping of sorghum + redgram in 2:1 ratio should be followed. Seed treatment with Imidacloprid 70 WS @ 5ml/kg or Thiamethoxam 70 WS @ 3 g/kg of seed may also be used. Soil application of Carbofuran 3G granules@ 20kg/ha in furrows at the time of sowing or spraying should be done at the seedlings stage.

2. Stem borer

It attacks the crop from 2nd week after germination until crop maturity. Irregular-shaped holes on the leaves are caused by the early instar larvae feeding in the whorl. Drying of central shoot giving "dead-heart" is observed and extensive stem tunneling is also found. Peduncle tunneling leads to breaking of peduncle, which results in complete or partial chaffy panicles.

Leaf damage

Deadheart

Control measures

Uproot and burn stubbles and chop of stems of previous crop to prevent its carryover. Need-based whorl application of Carbofuran 3G @ 8-12 kg/ha inside the leaf-whorls of infested plants at 20 and 35 days after emergence reduce damage. Inter-cropping of sorghum with cowpea is also advised.

Stem tunnels

Adult

3. Fall army worm

Fall army worm (FAW) is a polyphagous pest feeding on over 100 recorded plant species belonging to 27 families. However, it prefers plants from Gramineae family including many economically important plants such as maize, sorghum, millets, sugarcane, paddy, wheat etc.

Larvae of FAW damaging whorl

Later instar damage of whorl

The young larvae (Ist to IInd instar) scrape both of the leaves skeletonising the upper epidermis leaving silvery transparent membrane. The IIIrd instar larvae, the larvae enter the whorl and inflict ragged edged oblong holes on leaf lamina presenting ragged edged holes. Once the larvae reaches fifth instar it feeds voraciously causing extensive defoliation of the whorl. On an average 1-2 larvae were found in each whorl.

Control measures

Following are the management options suggested to manage the pest.

General management measures

- Deep ploughing of the field exposes the FAW larvae and pupae to sunlight and natural enemies

- For synchronous planting sow the crop within the sowing window so that single stage of crop is available.
- Deploy pheromone traps @ 12 traps / ha for monitoring the FAW.
- Collect and destroy egg masses/ larvae during scouting
- Erect bird perches @ 25/ha. soon after sowing as it facilitates movement of insectivorous birds *viz*., black drongo and swallows which predate on flying moths as well as caterpillars.

Early instars (I – II)

- Treat the millet seed with mixture of Cyantraniliprole 19.8 % + Thiomethoxam 19.8% @ 4 ml/ kg of seed as it protects the crop up to three weeks which in turn helps the crop to establish with good initial plant vigour (Based-on results of adhoc trials at IIMR, Hyderabad, *Kharif*, 2019)
- When incidence is low or at early instar stage (7-30 day old crop), spray *Azadirachtin* 1500 ppm @ 5ml/liter or 5% Neem seed Kernel extract (NSKE).
- Spray with fungal pathogen, Nomurea *rileyi* (1 x 10^8 cfu@ 3 grams per liter of water
- In case of severe infestation (> 10% damage) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l water or *Chlorantraniliprole* 18.5 @ 0.3 ml/lit of water or or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water. Alternate the chemical in subsequent sprays to avoid build-up of resistance in pest against insecticide.

Mid instars (III – IV)

- Collect egg masses and larvae and destroy
- Apart from insecticides application of mixture of sand (10kg) and lime 50 grams into the whorls, harms the larvae protecting the crop. This was observed at farmers field.
- In case of severe infestation (10 – 20 % damaged plants) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l water or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water. Alternate the chemical in subsequent sprays. Spray using high volume sprayer (Knapsack) preferably in the morning or evening with nozzle directed towards the whorls is advised.

Late instars (V- VI)

- The late instar larvae are very difficult to manage using chemicals. In case of presence of late instar larvae poison baiting is suggested with fermented mixture of rice bran. Keep the mixture of 10 Kg rice bran + 2 Kg jaggery with 2-3 litres of water for 24 hours to ferment. Add 100 g Thiodicarb just half an hour before application in the field. The bait should be applied into the whorl of the plants.
- In case of severe infestation (> 20% damaged plants) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water or or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water.
- Spray using high volume sprayer, the nozzle directed towards the whorls for better control. The subsequent spray may be taken up after 10 -15 days depending on the intensity of infestation avoiding the previously sprayed chemical.

Major diseases

1. Grain mold

Grains show symptoms of fungal infection and develop fungal bloom of various colour (black, white or pink) depending on infecting fungus. The infected grains are light-weight, soft, powdery, low in nutritional quality, poor in germination and low in market acceptability for human consumption.

Control measures

Use of mold tolerant varieties and harvesting of the crop at physiological maturity followed by drying of the grain. Spray of Propiconazole @ 0.2% starting from flowering and another spray after 10 days is recommended.

2. Downy mildew

The most conspicuous symptom is the appearance of vivid green and white stripes on the leaves and white patches of oospores on the lower surface of infected leaves. Systemically infected plants become chlorotic and such plants usually fail to throw panicles. Even if panicles are exerted, they are small and have little or no seed set.

Control measures

Deep summer ploughing before planting to reduce soil borne oospores is much helpful. Seed dressing with Metalaxyl or Ridomil 25 WP@ 1g a.i./kg followed by foliar spray with Ridomyl-MZ @ 3g/L water is recommended.

Harvesting

Kharif sorghum should be harvested immediately after it reaches normal maturity to reduce chances of mold development. The panicles are harvested first and remaining plants later. The harvested panicles are left in the field for about a week for drying and thereafter the grains are separated from panicles by threshing manually or by mechanical threshers.

Drying / Bagging

After threshing, the grains are sundried for 1-2 days to reduce the moisture content to 10-12%. Bagging of the grains is done in plastic or gunny bags for immediate marketing.

2. Post-rainy (*rabi*) sorghum

(Sorghum bicolor (L.) Moench)

Common name: Jowar, Great millet

Vernacular names: *Jwari* (Marathi), *Juar* (Bengali, Gujarati), *Jola* (Kannada), *Cholam* (Malayalam, Tamil), *Janha* (Oriya), *Jonnalu* (Telugu), Other names: *Milo*, *Chari*

Improved cultivation practices

Preparation of land

One deep ploughing with mold board plough in summer followed by 3 to 4 harrowing is recommended to attain good seed bed and maintain weed free conditions. To improve the water retention, compartmental bunds of 10m × 10m in the month of August is recommended.

Method and time of sowing

The crop is sown by bullock drawn seed drills with 2 or 3 coulters at 5-7 cm depth in the soil. The seeds are covered by one harrowing after sowing by seed drill. It is also sown by tractor drawn seed drill with 4 coulters with simultaneous covering of seeds by blade attached to the seed drill.

1. Selection of high yielding cultivars

The *rabi* sorghum varieties and hybrids recommended for different states are as follows.

State	Area of adaptation	Hybrids	Varieties
Maharashtra	Rain fed areas (Medium to deep soil)	CSH 39R, CSH 19R, CSH15R	Phule Rohini (RPASV3), Phule Suchitra (RSV 1098), CSV 216R, CSV 29R, CSV 22R, CSV 18R, Parbhani Super Moti
	Irrigated areas	CSH 39R, CSH 19R, CSH15R	PKV Kranti, CSV22R, Phule Vasudha
	Shallow soil	-	CSV 26R, Phule Anuradha, Phule Chitra
Karnataka	Dry zones (deep soil)	CSH 15R	BJV 44 (SPV 2034), SPV 2217, CSV 29R, M 35-1, DSV4
	Transitional zones (médium soil)	CSH 15R	BJV 44 (SPV 2034), SPV 2217, CSV 26R, DSV5
	Irrigated zone	CSH 39R, CSH 19R, CSH 15R	BJV 44 (SPV 2034), SPV-2217, CSV 29R, CSV 22R, DSV5
Telangana	Normal rabi areas	CSH 15R	CSV 29R, CSV 26R, CSV 22R, CSV 18R
Tamilnadu	Entire rabi area	CSH15R	CSV 29R, CSV 26R, CSV 18R, CSV 22R
	Summer sorghum areas	CSH15R	CO 26, CO 24, COFS 29, CSV 33MF
Gujarat	Entire rabi zone	CSH 15R	CSV 29R, CSV 26R, CSV 18R

Time of sowing

The optimum sowing time for *rabi* sorghum is 2nd fortnight of September to 1st fortnight of October. In double cropping practice, sowing is extended up to 2nd fortnight of October.

Seed rate, spacing and plant population

Seed rate of 8-10 kg/ha or 3 kg/acre is recommended. Spacing between row to row is 45 cm and plant to plant spacing within row is 15 cm. Plant population in rainfed conditions is 1.35 lakh/ha and in irrigated conditions is - 1.5 to 1.8 lakh/ha (15-20 plants per square meter).

Nutrient management

For rainfed (shallow to medium soil) conditions, apply 40:20:00 kg of NPK/ha as basal dose. For rainfed (deep soil) conditions, apply 60:30:00 kg NPK/ha as basal. For irrigated conditions apply 80:40:40 kg of NPK/ha (N in two equal splits 50% as basal and 50% at 30-35 DAS, full P and K at time of sowing).

Inter-cultivation and weed control

Inter-cultivation 2 or 3 time at 3, 5 and 7 weeks after sowing should be done to check the weed growth, which also helps to conserve soil moisture by providing top soil mulch.

Weed management

It can be done by application of Atrazine @ 0.5 kg a.i/ha as spraying on the soil as pre-emergence application immediately within 48 hours after sowing.

Water management

Under irrigated conditions in medium-deep to deep soils, three irrigations - first at germination, second at panicle initiation and third at grain filling stage are desirable. Optimum irrigation schedule consists of five irrigations each at 35, 55, 75, 85 and 105 days after sowing, which coincides with physiological stages of panicle primordial initiation, boot leaf, flowering, milky and dough stages, respectively. In case of limited availability of irrigation water, it can be restricted to one irrigation and it should be at flower primordial stage or boot leaf stage depending on the soil moisture situation.

Crop-based cropping system

Rabi sorghum can be grown in medium to deep soil where the rainfall frequency is high giving a suitable fallow period after rainy (*kharif)* sorghum. However, double cropping of black gram/ green gram/ cowpea (fodder) and *rabi* sorghum is recommended wherever found operationally feasible. Soybean + *rabi* sorghum sequence cropping is found feasible and profitable in irrigated conditions. Intercropping of sorghum with safflower at 4:2 or 6:3 ratio is recommended on deep soils.

Insect pests and disease management

Insect pests

a) Shootfly

It is a seedling pest and normally occurs in the 1st- 4th week after germination. Maggot feeds on the growing tip causing wilting of leaf and later drying of central leaf giving a typical appearance of 'dead heart' symptoms.

Cultural control: Sowing in the September end to October first week is ideal to escape shootfly damage. Another important practice is to increase the seed rate and destroy the 'deadheart' seedlings after their removal, to maintain the optimum plant stand.

Chemical control: When sowing is delayed, the shoot fly can effectively be controlled by seed treatment with Imidacloprid 70WS @5gm/kg of seed or Thiamethoxam70WS @3g/kg of seed. Basal application of Carbofuron 3G at the time of sowing as soil application in the soil furrows @ 20 kg/ha can also effectively check the pest incidence.

b) Fall army worm

Details are given in the previous chapter No. 1 which needs to be followed.

c) Stem borer

It infests the crop from 2nd week till maturity. Initially, the larvae feed on the upper surface of whorl leaves leaving the lower surface intact as transparent windows. As the severity of the feeding increases, blend of punctures and scratches of epidermal feeding appears prominently. Sometimes 'dead heart' symptoms also develop in younger plants due to early attack. Peduncle tunneling results into either breakage or complete or partial chaffy panicles.

Cultural control: The carryover of the pest from one season to another is through stubbles left in the field as well as the stems/stalks kept for use as fodder after harvest. Uprooting and burning of stubbles and chopping of stems prevent its carryover.

Chemical control: The borer can be controlled by whorl application of Carbofuron 3G @ 8-12 kg/ha at 20 and 35 days after emergence.

d) Shoot bug

Heavy infestation is seen on the *rabi* crop, when rain occurs at seedling stage. The nymph and adult suck the plant sap which reduces plant vigour and cause yellowing. In severe cases, the younger leaves start drying and gradually extends to older leaves which may lead to complete death of plant.

Shoot bug nymphs & adults

Yellowing of leaves

Control measures: Alternate host grasses as related should be removed to prevent build-up of shoot bug.

Chemical control: Application of Carbofuran 3G @ 8 kg/ha in the whorls can effectively check the incidence of the pest.

e) Aphids

Aphids and nymphs prefer to feed leaves. It also attacks during boot stage, which may result in poor panicle exertion. Both the nymphs and adults suck the sap and heavily infested leaves show yellowish blotches and necrosis may occur on leaf

Aphid infested leaf

edges. They produce abundant honeydew which predisposes the plant to sooty mold and other sporadic fungal growths. Severe damage under moisture stress conditions results in drying of leaves as well as plant death.

Control measures: Spraying of Metasystox 35 EC (@ 1000 ml/ha in 500 L water effectively control aphids.

Diseases and their management

a) Charcoal rot

Symptoms

Softening of the stalk at the base and premature lodging of the crop. Losses in seed size, grain yield and quantity or quality of fodder.

Management

Minimal doses of nitrogen fertilizer and low plant densities reduce charcoal rot. Moisture conservation practices like, wheat straw mulch will provide marginal advantage in checking the disease symptoms. Seed treatment with talc-based formulation of *Pseudomonas chlororaphis* @ 10g/kg seed is recommended.

Charcoal rot

b) Stripe virus

Appearance of continuous chlorotic stripes/bands between the veins of the infected leaf. Affected plants appear stunted in growth. Early infected plant dies sooner or later without emergence of panicle. Plants infected at later stages appear dwarf with short internodes, show partial exertion of panicle having few or no seed formations.

Management

Avoid sowing in early September as disease incidence become more and sow during early to mid-October. For vector management spray Metasystox 35 EC or Methyl-S-demeton 35 EC @ 5ml/10L water at 15 days interval starting from 20 DAE.

Stripe virus

Harvesting and threshing

Crop should be harvested at maturity (110-120 days after sowing) depending upon the genotype's duration. The panicles are harvested first and remaining plants latter. Sometime harvesting can be done by uprooting of the whole plan. The harvested panicles are left in the field for about a week for drying and thereafter the grains are separated from panicles by threshing manually.

Drying and Bagging

After threshing the grains are sundried for 1-2 days to reduce the moisture content up to 10-12%. Bagging of the grains is done in plastic or gunny bags for immediate marketing.

3. Forage sorghum

(Sorghum bicolor (L.) Moench)

Common name: Jowar (Hindi), Great millet, *Chara, Chari*

Vernacular names: *Jwari* (Marathi), *Juar* (Bengali, Gujarati), *Jola* (Kannada), *Cholam* (Malayalam, Tamil), *Janha* (Oriya), *Jonnalu* (Telugu), Other names: *Milo, Chari*

Types of forage sorghum

There are different types of forage sorghum, which are in use in our country or in western countries. The most fundamental management decision, a forage sorghum producer makes is how the forage will be utilized, which in turn determines the type and variety of forage sorghum to grow. In India, single-cut, multi-cut and dual-purpose genotypes are popular. The main types of forage sorghums are sudan grass varieties, sudan × sudan grass hybrids, grain sorghum × sudan grass hybrids, grain sorghum × grain sorghum hybrids and dual-purpose varieties. In general, in the northern belt, sudan grass varieties and grain sorghum × sudan grass hybrids are popular.

Climate

Relative humidity of 80-85% is suitable for crop growth in *kharif* and 500-750 mm average rainfall, and optimum temperature of 33-34 ˚C in *kharif* is ideal for good growth. Temperature above 24-25 ˚C during *rabi* is suitable. Optimum soil temperature is 18-21˚C for good germination.

Soil requirement

Leveled and well drained land with loam, sandy loam, light and average black soil having good drainage are suitable and 6.5 to 7.5 pH is optimum for good plant growth.

Varieties: The list of latest and popular varieties recommended for different states are given below.

State	Single cut varieties	Multi-cut hybrids	Multi-cut varieties
All India	HC 308, PCH 106, Pant Chari 5, CSV 30F, CSV 21F	CSH 20MF, CSH 24MF	CSV 33MF, SSG 59-3, Pusa Chari 6, Pusa Chari 23
Haryana	JJ 20, JS 263, JS 29-1, HJ 513, HJ 541	-	-
Punjab	-	Punjab Sudex Chari 1, Punjab Sudex Chari 4	SL 44

State	Single cut varieties	Multi-cut hybrids	Multi-cut varieties
Tamilnadu	K1, K7, CSV 32F	-	CoFS 29, CSV 33MF
Gujarat	GFSH 1, GFS 5	-	GFS4
Rajasthan	Pratap Chari 1080	-	-
Uttarakhand	Pant Chari 7		Pant Chari 6 Pant Chari 8
Maharashtra	Ruchira, CSV 32F	CSH 24MF	CSV 33MF

Field preparation and sowing

One summer ploughing followed by 2-3 harrowings and planking are required for clump free and finer tilth. Sowing time of sorghum depends on soil temperature, weather parameters and harvesting scheme of the crop etc. However, March 20 to April 10 is the best period for summer sowing and for monsoon season, sowing should be done at the first showers. The multi-cut varieties/hybrids should be sown in first fortnight of April. The planting time can be extended up-to first week of May depending on the availability of land and irrigation. Usually, the onset of monsoon or second week of June is suitable for single cut forage sorghum.

Seed rate and seed treatment

Multi-cut forage sorghum

Seed rate is 10 kg/ha with spacing of 45 cm between rows and time of sowing is April – mid May, irrigation as and when required or at 7 to 10 days interval in summer season.

Single-cut forage sorghum

Seed rate is 25 kg/ha with spacing of 30 cm between rows, time of sowing is June (with onset of monsoon)

Method of sowing

For proper germination seed should be sown at a depth of 2.5-4.0 cm in rows with 25-30 cm spacing. In case, the field has not been prepared, sowing should be done through broadcasting with 15-20% higher seed rate.

Fertilizers and nutrient management

Sorghum being a cereal and high biomass crop requires balanced fertilizer to get higher yields. In case of single-cut varieties, 80 Kg N per ha in two split doses is optimum under irrigated condition. First half is applied as basal during last ploughing or at the time of sowing and remaining half is to be applied after 35-40 days after sowing when there is adequate moisture in the soil. In rainfed areas, 40 kg N/ha as basal is preferred.

In multi-cut varieties, 100-120 kg N per ha is recommended in three split doses. First, one-third of it should be applied at the time of sowing. The second dose of one-third is given after the first cut and remaining one-third after second cut. These split doses should be given when there is adequate moisture in the soil.

Integrated nutrient management

Apply 8- 10 ton/ha compost or FYM before sowing in poor light soils. Use 35-45 Kg Nitrogen/ha at 35-40 days after sowing in single cut (or) 10-15 ton/ha compost/ FYM before sowing 40-45 Kg Nitrogen/ha in equal split dose after each cutting (except last-cut) in multi-cut sorghum.

Irrigation / water management

Generally, sorghum crop sown in rainy season does not require any irrigation. One or two irrigations can be given at an interval of 15-20 days as and when need arises or during prolonged dry spell. Water stagnation should be avoided.

Crop sown in March/April will require first irrigation after 15-20 days of sowing and subsequent irrigations at an interval of 10-15 days are recommended. In multi-cut varieties, the crop should be irrigated immediately after every cut for better regeneration and faster growth.

Weed management

Common weeds are Motha - *Cyperus rotundus,* Doob -*Cynodon dactylon and* Other broad-leaf weeds.

Weeds are a major problem in initial stages of crop growth and compete for water and nutrients. Well prepared land, optimum seed rate and good germination usually suppress the weeds at early stage and later, crop canopy does not allow weeds to survive. Summer ploughing to keep field weed free and 1-2 hand weedings after 15-20 days of crop sowing reduces weeds considerably. The pre-emergence spray of Atrazine @ 0.5 kg a.i/ha effectively controls the weeds. Spray of weedicide should be taken up immediately after 48 hrs of sowing, and it needs to be ensured that the soil surface is moist.

Integrated weed management

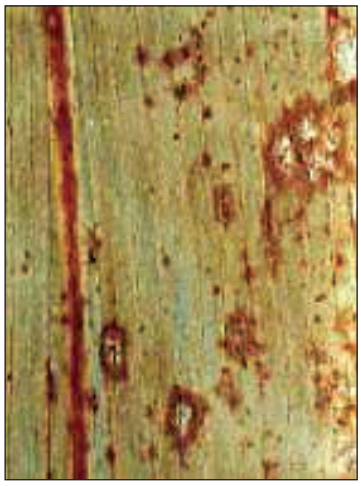
It comprises of summer ploughing, well prepared land, 1-2 hand weedings and use of optimum seed rate with seeds having good germination percentage.

Insect-pests and their management

Same as grain sorghum, but foliar sprays and systemic chemicals need to be avoided as the whole plant is the fed to cattle at flowering or cutting stage.

Diseases and their management

Diseases that are observed on grain sorghum also appear on forage. Leaf diseases like anthracnose, zonate and gray leaf spots are common on forage. For management of these diseases foliar sprays with systemic chemicals to be avoided on grown up plants.



Anthracnose

Zonate

Gray leaf spot

Cropping systems

Mixed cropping

Planting of legumes like cowpea, cluster bean, greengram, blackgram or pigeonpea along with fodder sorghum in 2:1 ratio increases fodder yield and quality. In low rainfall or less irrigated areas, mixed cropping of sorghum and guar is desirable. In irrigated or high rainfall areas, mixed cropping with cowpea gives high green fodder yield. The erect variety of fodder cowpea is preferred.

Crop rotation

The yield of sorghum is high when planted after leguminous crop like berseen, and lucern. It saves nitrogen application to sorghum crop. Popular crop rotation with fodder sorghum includes, fodder sorghum-berseen-maize + cowpea (one year), fodder sorghum-oat- maize + cowpea (one year), maize (grain)-wheat-fodder sorghum + cowpea (two year), fodder sorghum-pea (grain)-sugarcane (two year).

Harvesting

The quality of forage is dependent on the stage of harvesting of the crop. As the crop matures, there is a decrease in leaf/stem ratio and increase in lignifications of forage. Single-cut varieties are harvested at 50% flowering. At that stage HCN is reduced to safer limits and quality of fodder is good. In multicut varieties, first cut taken at 55-60 days after sowing and subsequent cuts at 35-45 days interval give higher green fodder yield and dry matter production. Harvesting of multicut sorghum should be done 5-8 cm above ground level to obtain good regeneration after cutting.

Fodder yield

On an average, green fodder yield of improved single-cut varieties is around 40-45 t/ha whereas, multi-cut varieties/hybrids may yield 60-90 t/ha green fodder in 3-4 cuts if sowing is done during March (mid) – April (first week).

4. Sweet sorghum

(Sorghum bicolor (L.) Moench)

Common name: *Meethi Jawar*, Sweet sorghum

Vernacular names: *God Jwari* (Marathi), *Misthi Juar* (Bengali, Gujarati), *Jola* (Kannada), *Cholam* (Malayalam,Tamil), *Janha* (Oriya), *Jonnalu* (Telugu), Other names: *Meethi Jawar*

Sweet sorghum - promising alternate biofuel crop

Sweet sorghum similar to grain sorghum, but accumulate sugars (10-15%) in its stalks as in sugarcane. It is a potential alternative feedstock with less water and input requirement crop than those of sugarcane from which molasses is obtained. The bagasse after extraction of juice from sweet sorghum has higher calorific value and hence, can be used to generate power. Bagasse can also be used as animal fodder after suitable processing and also as a substrate for production of second-generation cellulosic ethanol. Biofuel include fuel derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases. The biofuel development programme especially lignocellulosic bioethanol received highest priority of late considering the long term economic, environmental and social benefits.

Characteristics of sweet sorghum

- High biomass productivity (45–80 t ha^{-1}).
- High Brix (soluble sugars) (16–20%).
- Thick stems and juicy internodes with maintenance of stem juiciness until maturity.
- Photo- and thermo-insensitivity so that it can be grown throughout the year and fit into diversified cropping systems.
- Good digestibility of residues when used as forage or for lignocellulosic ethanol production.
- Tolerance to mid-season and terminal drought.
- High water and nitrogen-use efficiencies.
- Grain yield (3.0 – 5.0 t ha^{-1}).

Crop adaptation

Sweet sorghum can be grown under dryland conditions with annual rainfall ranging from 550-750 mm. The best areas to produce this crop are central and south India, subtropical areas of Uttar Pradesh and Uttaranchal. It can be grown on well-drained soils such as silty-loam or sandy, clay-loam soils with a depth ≥ 0.75 m. Atmospheric temperatures suitable for sweet sorghum growth vary between 15 and 37 ^{o}C. Sorghum being a C_4 species is adapted to wide range of environments with latitudes ranging from 40 ^{o}N to 40 ^{o}S of equator. Sorghum in general has relatively deep root system (>1.5 m), and has unique feature of undergoing "dormant" under unfavorable conditions and resume growth once environmental conditions are favorable for growth.

Soil

Medium to deep black soil (Vertisol) or deep-red-loamy soil (soil depth: ≥0.75 m deep) holding at least 500 mm of plant available water (PAW) is suitable for this crop.

Latest sweet sorghum cultivars

Sweet sorghum varieties and hybrids have the ability to produce extremely high stalk yields of up to 50 t ha^{-1}, with juice brix between 18% and 22% and 1.5 to 2.5 t ha^{-1} grain. Sweet sorghum improvement programmes have resulted in the identification of several promising sweet sorghum varieties such as SSV 96, GSSV 148, SR 350-3, SSV 74, HES 13, HES 4, SSV 119 and SSV 12611 for TSS% and juice yield; GSSV 148 for cane sugar, NSS 104 and HES 4 for green cane yield, juice yield, juice extraction and total sugar content; and RSSV 48 for better alcohol yield. The performance of nationally released cultivars during *kharif* season across AICRP locations is given in below. The yields may vary according to the location, date of planting, soil type, season (*Kharif* or *Rabi*) and rainfall distribution etc. Stalk yields obtainable during *rabi* will be 30-35% less with reduced sugar content than *kharif* and summer grown crops because of prevailing low night temperatures and shorter day lengths and their interaction with planting time.

Details of nationally released cultivars

Entry	Year of release	Days to flower	Days to maturity	Fresh stalk yield (t. ha^{-1})	Brix (%)	Juice yield (L. ha^{-1})	Calculated ethanol yield (L ha^{-1})
SSV 84	1992	84	124	35-40	17-18	12000-14000	1000-1100
CSV 19SS	2005	78	120	35-40	17-18	12000-14000	1000
CSH 22SS	2005	82	119	44-52	17-18	14000-18000	1100-1300
CSV 24SS	2011	81	119	35-40	17-18	14000-15000	1100-1200

Improved production technology

Land preparation and manuring

Two ploughings followed by leveling for good soil tilth is required. Apply 10 t FYM along with last ploughing.

Sowing time

***Kharif* season crop (June-October):** Sowing should be taken immediately after the onset of monsoon, preferably from second week of June to first week of July, depending on the onset of monsoon. Sow

about three seed per hill by hand dibbling or planter at 5-cm deep. Please make sure that soil has fully charged with rainwater at least in the top 30 cm soil layer to ensure uniform germination. Soil moisture should be above equal or above field capacity at the time of sowing the crop.

***Rabi* season crop (October–February):** Planting should be carried out from last week of September to first week of November. The night temperatures should be above 15 °C at the time of sowing. Irrigate the crop if there is no rainfall at the time of sowing to ensure uniform germination and establishment.

Summer season crop: Planting can be done from mid-January to end of May under irrigated condition. The night temperatures should be above 15 °C at the time of sowing. The crop can also be grown in rice fallows in coastal areas capitalizing residual soil moisture.

Fertilizer management

Total 80 kg N, 40 kg P_2O_5, and 40 kg K_2O is recommended. Apply 50% N, full P_2O_5, and K_2O at sowing as basal dose. Apply remaining 50% N as side-dress at two equal installments at about 25-30 DAS (i.e. at final thinning) and at about 50-55 DAS after ascertaining the availability of soil moisture.

Seed rate: 8 kg/ha (or 3 kg/acre) is recommended

Spacing: Row to row distance of 60 cm; and plant to plant distance of 15 cm is recommended.

Plant population: Population of 1.10 to 1.20 lakh plants per ha (40000 to 48000 plants per acre) is optimum for realizing maximum productivity. Raising sweet sorghum with excessive plant population than recommended will result in the production of thin stalks that will lodge due to heavy winds or rains.

Thinning

First thinning need to be carried out at about 15 DAS and retain two seedlings per hill at 15 cm apart. Second (final) thinning need to be carried out at about 25-30 DAS to retain single plant per hill. Thinning operation is very essential for uniform stand establishment and optimum growth of plants.

Weed management

Use pre-emergence spray of atrazine @1.0 kg a.i./ha within 48 h after sowing under moist condition. Mechanical weeding twice up to 35-40 days age of the crop to check the weed growth is recommended.

Inter-cultivation

Inter-cultivation with blade harrow or cultivator once or twice between 20 and 35 days after sowing to not only check the weed growth but also conserve soil moisture by providing surface soil mulch.

Irrigation/rainwater management (*kharif*)

- Normally the crop is raised under rainfed condition in areas receiving rainfall of 550-750 mm. In case of late onset of monsoon and its erratic distribution, plant the crop and irrigate immediately.
- Irrigate the crop if the dry spell (drought) continues for more than 20 days on deep soils and more than15 days on medium/sandy loam soils especially at critical crop growth stages such as panicle initiation (35-40 DAS) and boot stages (55-65 DAS).
- Please ensure that crop does not suffer from moisture stress especially during pre-flowering stages of crop development. Sweet sorghum is aimed at maximizing the cane yield similar to sugarcane.

- Maintain soil always at field capacity. On the other hand, drain out the excess irrigation water or rainfall from the field to avoid water logging.
- Decide when to irrigate sweet sorghum based - on the soil type and rainfall distribution.

Tillering: Remove the side tillers (basal) manually, if they occur before 20-25 DAS from the base of the mother plant.

Crop protection

It needs to take need-based protection against shoot fly, stem borer and shoot bug, aphids etc. and other diseases as per recommendation based - on visual damage symptoms. The important insect pests and diseases that need attention and their management are given below.

Insect-pest

Shoot fly

Basal application of Carbofuran 3G (@ 20 kg ha^{-1}) at the time of sowing as soil application.

Spotted stem borer

Application of carbofuran 3G inside the whorl @ 8 kg/ha based on leaf feeding damage symptoms.

Shoot bug

Application of Metasystox 35EC (@ 2ml/lit of water) in the whorls based - on the damage symptoms.

Sugarcane aphids

Spraying of metasystox 35EC (@ 1000 ml/ha in 500 lit of water) at boot stage based on the damage symptoms.

Spider mites

Spraying of Kelthane 35EC or Dimethoate 35EC (@ 1000 ml/ha in 500 lit of water) at panicle emergence based on damage symptoms.

Diseases

Stalk diseases

Because of high sugar condition stalks are prone to red-rot, and pokkah boeing disease. Need-based application of agrochemicals may be required.

Downy mildew

Seed treatment with apron excel (@ 3 ml/kg seed)

Foliar diseases

Spray dithane M 45 (@ 2 g /lit water) at stage panicle initiation (35 DAS)

Harvesting

Harvest the crop at about 40 days after flowering of the plants, i.e. at physiological maturity of grain where black spot appears on the grain at the lower end. Alternately, the brix of standing crop can be measured using hand - held refractometer. Additionally, the plants can also be sampled for small mill test (SMT) to assess the juice brix and other quality parameters as it practiced in sugarcane. Harvest the

panicles at the last internode and thresh the grains separately followed by drying. Harvest the stalks to the ground level using sickle and remove the leaves including sheaths. The harvested canes can be stacked in small bundles of 10-15 kg and must be transported within 24 h of harvesting to the mills for crushing.

Bio-ethanol from sweet sorghum

The convertibility of high biomass lines of sorghum to bioethanol is of special interest as the use of sorghum biomass for biofuel production will not lead to food crisis. Sweet and forage sorghums have high yield potential i.e. up to 20-40 t/ha dry biomass and above 100 t/ha fresh biomass and they are good source of cellulose and hemicelluloses. Some sweet sorghum lines yield juice about 78% of total plant biomass and contains soluble fermentable sugars from 15 to 23% (by comparison, sugarcane has 14–16%). The sugar is composed mainly of sucrose (70–80%), fructose and glucose. The large scale cultivation of sweet sorghum can happen if improved cultivars with higher sugar yield with multiple biotic and abiotic stress tolerance are available besides the policy support from Government of India to incentive producers and processors.

5. Sorghum in rice fallows under zero-tillage

Adaptation

Despite of its multiple uses as food, feed, fodder and bio-fuel, the area under grain sorghum in India has declined from 10.25 m ha in 1999-2000 to 4.96 m ha in 2017-18. In rice-fallows of coastal Andhra Pradesh, sorghum cultivation is gaining popularity among farmers due to its high productivity (5.66 t/ha in 2017-18) whereas, the national productivity is very low (average yield is below 1.0 t/ha). The farmers are commercially motivated and selected to grow sorghum instead of maize on residual moisture of rice-harvested field without tillage operation after comparing economic benefits. The new opportunities and areas for sorghum cultivation are emerging. Due to delayed transplanting of rice owing to late release of water and severe infestation of yellow mosaic virus and weeds in blackgram, the farmers are switching over to non-traditional crops like, sorghum (in less irrigated areas) and maize (in assured irrigated areas) as an alternative to blackgram. Practically, the sorghum growers in this area are mostly inclined towards obtaining maximum monetary benefits from grain yields than others. Keeping these in view, proven hybrid along with package of practices were demonstrated in several farmers' fields in Guntur district of Andhra Pradesh. Of late, sorghum is being cultivated in rice-fallows after harvesting of rice on residual soil moisture. The farmers' preference is hybrids with high yield potential and medium height to avoid losses from lodging. Being new area of sorghum, farmers were not aware about high yielding sorghum hybrids of public sector and growing locally available private hybrids namely, *Maheco* 51, *Haritha, Kaveri* and *Mahalaxmi* 296. However, the experimental trials ascertained that hybrid CSH 16 yielded substantially higher grain up to 8 t/ha than 17 public and private cultivars tested. It has medium plant height and found suitable for the rice-fallows. The concomitant increase in average sorghum productivity of Guntur district (5.6 t/ha in 2017-18) has been witnessed. The following major cultivation practices suitable for rice-fallows area were evaluated and validated in farmers' fields. These are documented for ready reference to new farmers as given below.

CSH 16 - Suitable hybrid with high yield potential	
Plant type	Medium height (~2.00 m)
Duration	110 days
Grain yield	8.0-8.5 t/ha (in rice-fallows)
Fodder yield	11.5-13.7 t/ha (in rice-fallows)
Salient features	Medium tall, long loose panicle, medium bold seed, tolerant to grain mold and resistant to leaf spot disease and lodging, easily digestible fodder for cattle

CSH 14 - Suitable hybrid with high yield potential	
Plant type:	Medium height (~2.00m)
Duration	105 days
Grain yield	3.7-4.0 t/ha
Fodder yield	8.5-9.0 t/ha
Salient features	Medium tall, early maturing, semi-loose panicle, bold seed, tolerant to grain mould and leaf spot disease, suitable for low rainfall areas and intercropping

Seed rate

Seed rate of 7-8 kg/ ha (3 kg/acre) used by dibbling 3-4 seeds in each hole at 4 - 6 cm depth.

Seed treatment

Before sowing, treat sorghum seed with Imidacloprid 70WS @ 5 gm+2 gm Carbendazim (*Bavistin*) per kg of seed, or Thiomethoxam 3 g/kg of seed.

Spacing

Recommended row to row distance is 45 cm and plant to plant distance 10-15 cm. Maintain optimum plant population on the basis of soil response.

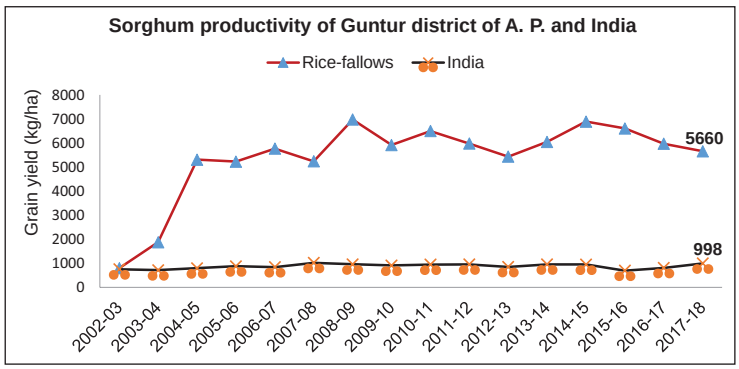
Fertilizer application

First dose of fertilizers: Half dose of N i.e. 40 kg per ha, full dose of P_2O_5 i.e. 40kg/ha and full dose of K_2O i.e. 40 kg/ha at sowing. Apply basal fertilizers in each hole at 6-8 cm at the time of sowing and cover it with pinch of soil before sowing the seeds.

Second dose of fertilizers: Apply half N dose i.e. 40 kg N before first irrigation at around 30-35 days after sowing.

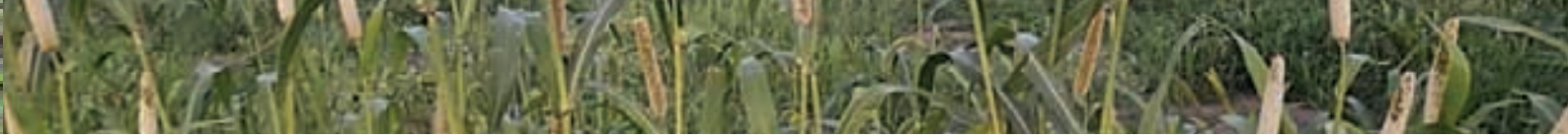
Harvesting and threshing

Crop should be harvested at physiology maturity (100-110 days after sowing) depending upon duration of the genotypes. The harvested panicles are left in the field for about a week for drying and thereafter, the grains are separated from panicles by threshing. The panicles are harvested first and remaining plants later.



Drying / Bagging

After threshing the grains are sundried for 1-2 days to reduce the moisture content up to 10-12 %. Bagging of the grains is done in plastic or gunny bags for immediate marketing.



6. Pearl millet (bajra)

(Pennisetum glaucum (L.) R. Br.)

Common name: Bajra

Vernacular names: Spiked millet or Pearl millet (English), *Bajra* (Bengali, Hindi, Oriya, Punjabi, Urdu), *Bajree* (Rajasthani, Gujarati, Marathi), *Sajje* (Kannada), *Kambu* (Tamil), *Sajja* (Telugu)

Improved package of practices

Preparation of land

Pearl millet can be grown in different soils. It does not grow well in soils prone to waterlogged conditions. The field should be ploughed once or twice followed by harrowing to create fine tilth.

Selection of high yielding hybrids and varieties

Most of the pearl millet area is grown with hybrids while the varieties are preferred in drought prone ecologies. The list of latest hybrids and varieties of pearl millet is given below.

Region/ State	Crop season	Hybrid	Variety
Rajasthan	*Kharif*	BHB-1202 (Bikaner Hybrid Bajra-1202), RHB 223 (MH 1998), HHB 299 (MH 2076), AHB 1200, MP 535 (Pusa Composite 701), MP 7872, MP 7792,HHB 272 (MH1837), HHB 67, MPMH-21, MPMH 17, KBH 108, GHB 905, 86M89, 86M86, 86M66, Kaveri Super Boss, Bio 448, RHB-173	MBC 2, PC 443, JBV 3, PC 383, ICMV 221, Raj 171
	Summer	Nandi 72, Nandi 70, 86M64	
	Kharif – arid parts	HHB 234, Bio 70, HHB-226, RHB-177	CZP 9802
Gujarat	*Kharif*	RHB 223 (MH 1998), HHB 299 (MH 2076), AHB 1200, MP 535 (Pusa Composite 701) , MP 7872, MP 7792, HHB 272 (MH1837), HHB 67, MPMH-21, MPMH 17, KBH 108, GHB 905, 86M89, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173	MBC 2, PC 443, JBV 3, PC 383, ICMV 221, Raj 171
	Summer	Nandi 70, Nandi 72, 86M64	
	Kharif – arid parts	HHB 234, Bio 70, HHB-226, RHB-177	CZP 9802

Region/ State	Crop season	Hybrid	Variety
Haryana	*Kharif*	RHB 223 (MH 1998), HHB 299 (MH 2076), AHB 1200, MP 535 (Pusa Composite 701) MP 7872, MP 7792, HHB 272 (MH1837), HHB 67, MPMH-21, MPMH 17, KBH 108, GHB 905, 86M89, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173,	MBC 2, PC 443, HC 20, JBV 3, PC 383, HC 10, ICMV 221, Raj 171
	Kharif – arid parts	HHB 234, Bio 70, HHB-226, RHB-177	CZP 9802
Punjab	*Kharif*	HHB 299 (MH 2076), AHB 1200, MP 535 (Pusa Composite 701) MP 7872, MP 7792, PHB 2884, KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173	PCB 164, ICMV 221, Raj 171
Delhi	*Kharif*	Pusa 1201 (MH 1849), HHB 299 (MH 2076), AHB 1200, MP 535 (Pusa Composite 701) MP 7872, MP 7792, KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171
Uttar Pradesh	*Kharif*	MP 535 (Pusa Composite 701) MP 7872, MP 7792, KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171
Madhya Pradesh	*Kharif*	MP 535 (Pusa Composite 701), MP 7872, MP 7792, KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, 86M86, 86M66, RHB-173	JBV 4, JBV 3, PC 383, ICMV 221, Raj 171
Maharash-tra	*Kharif*	HHB 299 (MH 2076), AHB 1200, Phule Aadis-hakti (DHBH 9071), Kaveri Super Boss, Pratap, PKV Raj, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	ABPC4-3, PC 612, Par-bhani Sampada, Samrud-hi, ICMV 221, Raj 171, ICMV 155
	Summer	Nandi 72, Nandi 70, 86M64	-
Tamilnadu	*Kharif*	HHB 299 (MH 2076), AHB 1200, CO 10, Co 9, Kaveri Super Boss, Pratap, Shine, MP 7792, 86M86, 86M64, 86M53, PAC 909.	PC 612, CoCu 9, Samrud-hi, ICMV 221, Raj 171, ICMV 155
	Summer	Nandi 72, Nandi 70, 86M64	-
Andhra Pradesh	*Kharif*	AHB 1200, Kaveri Super Boss, Pratap, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	PC 612, Samrudhi, ICMV 221, Raj 171, ICMV 155, Ananta
Karnataka	*Kharif*	Kaveri Super Boss, Pratap, Shine, MP 7792, PAC 909, 86M86, 86M64, 86M53	PC 612, Samrudhi, ICMV 221, Raj 171, ICMV 155

Method of sowing

Three systems of pearl millet sowing are followed: (i) on a flat surface, (ii) using ridge and furrow system, (iii) on a broad-bed and furrow system. The seed should be sown at 2.5 cm – 3 cm depth.

Time of sowing

Sowing of *kharif* pearl millet should be done with the onset of monsoon i.e. first fortnight of July in north and central parts of the country. First fortnight of October is appropriate time for *rabi* season

in Tamilnadu. Gap filling should be done by transplanting seedlings after 2-3 weeks of sowing if scanty population exists. In Marathwada area of Maharashtra, dry sowing prior to first monsoon rains is recommended. Summer pearl millet should be sown from 4 to 5th standard meteorological week (SMW) i.e. last week of January to 1st week of February to obtain higher production.

Seed treatment

Seed treatment with biopesticides (*Trichoderma harzianum*@ 4g/kg) or thiram 75% dust @ 3 g/kg seed will help against soil-borne diseases. Seed treatment with 300-mesh sulfur powder @ 4 g/kg seeds controls the smut disease. For removing ergot affected seeds, they are soaked in 10% salt solution. Seed treatment with metalaxyl (Apron 35 SD) @ 6 g/kg seed controls downy mildew. Seeds are treated with *Azospirillum* (600 g) and *Phosphobacterium* to enhance the availability of nitrogen and phosphorus.

Seed rate, spacing and plant population

The required seed rate for pearl millet is 3 kg/ha. For arid-western plain of Rajasthan, Haryana and Kutch of Gujarat (A1 zone), pearl millet should be planted in rows 60 cm apart, maintaining low plant population of 1.0 to 1.25 lakh/ha. For the area receiving rainfall more than 450 mm (zone A & B), the crop should be planted at aspacing of 45 × 10-15 cm between rows and plant to plant by keeping plant population of 1.75 to 2.0 lakhs/ha.

Seed rate should be used @ 3 to 4 kg/ha for obtaining required plant stand. The recommended plant population for pearl millet under normal conditions is 1,80,000 plants/ha (72,000 plants/acre). Under irrigation or high levels of management on highly productive soils, a population of 2,25,000 plants/ha (1,00,000 plants/acre) is recommended. On extremely sandy, droughty soils, a population of about 90,000 plants/ha (40,000 plants/acre) is desirable.

Nutrient management

Application of 40 kg N + 20 kg P_2O_5 per ha for arid regions and 60 kg/ha N + 30 kg /ha P_2O_5 for semi-arid regions is recommended for sole pearl millet as well as intercrop system. In light soils (sandy loams), the applied nitrogen may be lost due to leaching with heavy rains. So, only half of the recommended nitrogen dose should be applied at seed bed preparation. The remaining half of nitrogen dose is side-dressed when the crop is 25 days old. On soils which do not leach easily like, black soils, all of the nitrogen may be applied during seedbed preparation. Pearl millet seeds are sensitive to fertilizer burn. Do not apply fertilizer in the furrow with the seed or very near the seed in the row after sowing. It should be applied as side dressing.

Use of biofertilizer Phosphate Solubilizing Bacteria (*Azospirillum* and PSB) can economize the N and P fertilizer application. In zinc deficient soils of the pearl millet growing area of the country, application of $ZnSO_4$ 10 kg/ha is recommended. To correct the zinc deficiency in standing crop, spray of 0.2% $ZnSO_4$ at tillering to pre-flowering stage is recommended. Under prolonged dry spell, skip top dressing of N and spray 2% urea. Under excessive rain situation during vegetative phase, additional dose of N @ 20 kg/ha should be given.

Intercultivation and weed control

Two hoeings and weedings at 15 and 30 DAS are sufficient for controlling weeds effectively. The herbicidal weed control through pre-emergent application of atrazine @ 0.5 kg a.i./ha followed by with one hand weeding is effective. Second weeding helps to conserve soil moisture.

Pearl millet-based cropping systems in *kharif*

Rotation of cultivars should also be adopted to avoid downy mildew disease problem. Pearl millet hybrids and open-pollinated varieties should be used in alternate years/seasons. It is advised not to grow the same hybrid or open pollinated variety continuously on the same piece of land.

States	Crop rotation order
Rajasthan	Pearl millet + cluster bean/ cowpea/ green gram/ mothbean/ sesame
Haryana	Pearl millet + Green gram/ sesame / cluster bean/ cowpea
Gujarat	Pearl millet + Green gram/ sesame/ cowpea
Uttar Pradesh	Pearl millet + Green gram/ sesame/ cowpea
Madhya Pradesh	Pearl millet + Black gram/ soybean/ Pigeonpea/ cowpea
Delhi	Pearl millet + Pigeonpea/ groundnut/ castor
Punjab	Pearl millet + Chickpea/ fodder sorghum/ wheat
Maharashtra	Pearl millet + Mothbean / pigeonpea/ soybean/ blackgram, greengram/ cowpea/ sunflower
Karnataka	Pearl millet + Pigeonpea/ greengram/ sunflower/ soybean
Tamilnadu	Pearl millet + Pigeonpea/ greengram/ sunflower/ soybean/ cowpea
Andhra Pradesh& Telangana	Pearl millet + Pigeonpea/ greengram/ sunflower/ soybean/ groundnut

Irrigation

Under prolonged dry spells, irrigation should be given at critical stages of crop growth i.e. tillering, flowering and grain developmental stage, if water is available. In summer, pearl millet should be irrigated at regular intervals as per need of the crop.

Major insect-pests

Insect pests are considered to be relatively less important in most of the pearl millet growing areas in India. The most important insect pests of pearl millet are white grub, shoot fly and grey weevil.

White grub

A common pest in Gujarat and Rajasthan. The grubs attack the root of the growing seedlings and cause complete withering of the plants. Patchy gaps are formed due to death of plants which result in poor or uneven plant stand. Grubs cause maximum damage during July-August. The adults emerge from May to July with the pre-monsoon/monsoon showers and feed on pearl millet flower and grains in the milky stage. The extent of damage ranged from 5-25% in Rajasthan.

Control

Inter-cropping with sunflower and pigeon pea reduces the incidence of white grub. Collect and destroy the adult beetles immediately after first showers when they visit *neem/ Acacia* trees for mating.

White grub

Adult beetle

Damaged saeedlings

Furrow application of Carbofuran 3G @ 12 kg/ha with pearl millet seed and application at the time of sowing is effective. Soil drenching of Imidacloprid 17.8 SL @ 300 ml/ ha or Chloropyriphos 20 EC or Quinolphos 25 EC @ 4 lit/ha with irrigation in standing crop around 3 weeks of emergence of beetle or insecticide mixed soil can be used in rainfed crop provided it rains soon after application around three weeks later.

Shoot fly

It is a common pest on pearl millet in Gujarat and Tamilnadu. Larvae cut the growing point causing dead-heart during the seedling stage whereas in advance stage, they feed on ear heads and cut down panicles. Infestation is more on late sown crop.

Control

To control the shoot fly, the crop should be sown with the onset of the monsoon or improved within 10-15 days of first shower of monsoon. Recommended staggered sowing to contain the buildup of shoot fly population is to be adopted. Transplanting is suggested for late sown crop. In case direct seeding, a seed rate of 4 kg per ha is recommended and the affected seedlings are thinned within 15 days after sowing. In case of heavy incidence of shoot fly in endemic areas, spray the crop with 0.07% Cypermethrin at 10 and 20 days after germination and in places where water is a problem, 4% dust of Cypermethrin can be used.

Grass hoppers

Eggs are laid in the soil 75-200 mm deep; hoppers and adults feeds on foliage, at times causes severe defoliation. The adults are short winged and can fly short distances only.

Grass hoppers

Control

Weed free cultivation is advisable. After harvest, expose the egg through soil deep summer ploughing is recommended. Scrapping of bunds and clean cultivation should be done. Dust the crop with 4% Cypermethrin or Fenvalerate dust @ 25 kg/ha or spray the crop with 0.07% of Cypermethrin can be done.

Termites

A social insect that live underground in colonies, attack young seedlings as well as grown up plants. Infested plants wither and ultimately die.

Termites

Termite damaged crop

Control

Deep ploughing after harvesting of the crop, followed by collection of stubbles/plant residue and burning thereof. Use well decomposed FYM. Irrigate the crop timely. For managing termites where the pest is of regular occurrence, the soil should be mixed with Chloropyriphos 5D@ 35 kg/ha at the time of sowing. When the incidence of pest is noticed in standing crop dilute Chloropyriphos 20EC in 5 litre of water and mix it with 50 kg of soil and broadcast evenly in 1.0 ha followed by light irrigation.

Grey weevil

It is a polyphagous insect. Adult beetles feed on green leaves, cause serious damage to the seedlings.

Grey weevil

Control

To control this dusting of Quinalphos 1.5% or Methyl Parathion 2% or Malathion 5% @ 25 kg/ha is required on appearance of the pest.

Earhead bug

A common pest in southern parts of the country. Nymphs and adult bugs suck the sap from tender grains at the milk stage, making them chaffy/ shriveled.

Earhead bug

Shrivelled grains

Control

Early planting reduces the infestation of the pest, application of Carbaryl 50 WP @ 3 kg/ liter of water/ha.

Stem borers

A nocturnal moth, dirty brownish in colour. Caterpillars feed on foliage and bore into the stem causing dead heart, also tunnel the stem and bore into ear heads.

Control

Carbofuran 3G granules may be applied in the whorls @ 8-12 kg a.i./ha or the entire field can be sprayed with Metasystox 25 EC @2 ml /liter.

Major diseases

Although many diseases have been reported in pearl millet in India, but only few are important. These are downy mildew, smut, rust and blast. These diseases directly reduce grain yield by affecting grain formation. In addition, ergot can also reduce grain quality. Use of resistant cultivars is the most cost-effective method of the control of pearl millet diseases.

Downy mildew

Systemic symptoms as chlorosis generally appear on the second leaf and all the subsequent leaves and panicles of infected plant show symptoms. Leaf symptoms begin as chlorosis at the base of the leaf lamina and successively upper leaves show a progression of greater leaf

Downy mildew on leaf

area coverage by the symptoms. Infected chlorotic area produces huge number of asexual spores, generally on the lower surface, giving the leave a 'downy' appearance. Systemically infected plants remain stunted either do not produce panicle or produce malformed panicles.

Downy mildew on earhead

Management

Diseases can be controlled by integrating methods of chemical or biological control, and cultural practices. It is recommended to use of resistant cultivars, rotate hybrids with variety alternately to keep soil inoculum under control. Seed treatment with Apron 35 SD @ 6g/kg seed can be done. Seed treatment with *Bacillus pumulis* (INR7) is recommended. If infection exceeds 2-5%, foliar spray of Ridomil 25 WP (100 ppm) after 21 days of sowing can be done.

Rust

Rust symptoms first appear on lower leaves as typical pustules containing reddish brown powder. Symptoms can occur on both upper and lower surface of the leaves but mostly on upper surface and also on stem. Highly susceptible cultivars develop large pustules on leaf blades and sheaths.

Rust

Management

To control this problem use of resistant hybrids/varieties is advised. Sow the crop with onset of monsoon. Destroy collateral hosts like, *crabgrass* and *Guinea grass, buffalo grass* on the field bunds. Spraying of Dithane M 45 @ 0.2% thrice commencing from one month old crop onwards at 10 days intervals.

Smut

Smut disease is of greater importance in India especially, with the adaptation of hybrids. The disease is more severe in CMS-based single-cross hybrids than in open-pollinated varieties. The infected florets produce sori that are larger than grains and appear as oval to conical, which are initially bright green but later turn brown to black. The disease occurs during the month of September/ October. Early sown crop generally escapes from the smut infection.

Smut infection

Management

It can be managed by using of resistant cultivars. Seed dressing with Thiram 75 @ 3 g/kg is recommended. Remove smutted ears from the field covering in a plastic bag should be done.

Ergot

The disease is easily identified as a honeydew substance of creamy to light pinkish ooze out of the infected florets which contains numerous conidia. Within two weeks, these droplets dry out as hard dark black structures larger than seeds, protruding out from the florets in place of grain, which are

called sclerotia. The disease occurrence and spread is highly influenced by weather conditions during the flowering time.

Management

Mechanical removal of sclerotia from seed and washing of seed in 2% salt water. Adjust sowing dates so that ear emergence does not coincide with more rainy days. Plough the field soon after harvest so that ergot is buried deep. Three foliar application of Thiram 0.2% starting from 50% flowering reduces incidence.

Blast

The symptoms appear as distinct large, indefinite, water soaked, spindle shaped, grey centred and purple grey horizon with yellow margin, resulting in extensive chlorosis and premature drying of young leaves.

Management

Clean cultivation and removal of crop residues is must. Foliar spray with Carbendazim @ 0.1% a.i. is recommended if leaf symptoms are there.

Blast symptoms on leaves

Harvesting

The best stage to harvest pearl millet is when the plants reach physiological maturity determined by the black spot at the bottom of the grain in the hilar region. When the crop matures, the leaves turn yellowish and present a nearly dried up appearance. The grains are hard and firm. The usual practice of harvesting pearl millet is cutting the earheads first and the stalks later. The stalks (straw) are cut after a week, allowed to dry and then stacked. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 10%.

Threshing, cleaning, drying and storing

After drying ear heads they are threshed in a mechanical thresher or spread it and drag a stone roller over it or cattle threshes. Dry the seeds below 10 % moisture and mix 100 kg of grains with 1.0 kg of activated kaolin to reduce the rice weevil and rice moth incidence. Spray Malathion 50EC 10 ml/lit @ 3 Lof spray fluid/100 m^2 over the bags during storage in godowns. For grain purpose the grain should be dried well below 10% moisture and stored in gunny bags.

7. Finger millet

(Eleusine coracana L.)

Common name: *Ragi*
Vernacular names: *Ragi, Mandika, Marwah, Mandua (Hindi), Nagli, Nachni (Marathi), Ragi (Kannada), Ragulu, Chodi (Telugu), Keppai, Kelvaragu (Tamil), Marwa (Bengali), Nagli, Bavto (Gujrati), Mandia (Oriya), Mandhuka, Mandhal (Punjabi)*

Climate

Finger millet comes up well in tropical and subtropical climate and can be cultivated up to an altitude of 2100 m. The minimum temperature required is 8-10 ˚C. A mean temperature range of 26-30 ˚C during the growth is the best for proper development and good crop yield.

Soil

The crop is widely adaptable from mean sea level to foot hills of Himalaya and can be grown in range of soils. The crop can tolerate a certain degree of alkalinity. The best soil is alluvial, loamy and sandy soil with good drainage.

Improved varieties

A number of high yielding varieties have been evolved and released for cultivation in different states. The list of latest and popular varieties recommended for different states are given below.

S. No.	State	Varieties
1.	Karnataka	DHFM-78-3, Vakula (PPR 2700), Arjuna (OEB-526), VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), GPU 67, GPU 66, GPU 48, GPU 45, GPU 28, PR 202, MR 1, MR 6, Indaf 7, ML365, KMR 340, KMR 301, KMR 204
2.	Tamilnadu	VL Mandua 376 (VL 376), Arjuna (OEB-526), GPU 28, CO 15, TNAU 946 (CO 14), CO 13, CO 12, CO 9
3.	Andhra Pradesh & Telangana	VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), VR 847, PR 202, VR 708, VR 762, VR 900, VR 936, Vakula (PPR2700)
4.	Jharkhand	VL Mandua 379 (VL 379), VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), A 404, BM 2
5.	Orissa	VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), Arjuna (OEB-526), OEB 10, OUAT 2, BM 9-1, OEB 526, OEB532

S. No.	State	Varieties
6.	Uttarakhand	VL 379, VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), VL 348, VL 324, VL 315, VL 149, VL 146, PES 400, PRM 1, PRM 2
7.	Chattisgarh	Chhattisgarh Ragi-2 (BR-36), Arjuna (OEB-526), VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), VL 324, VL 315, VL 149, Indira Ragi1, Chhattisgarh 2, BR7, GPU 28, PR 202, VR 708 and OEB-526, OEB-532
8.	Maharashtra	VL Mandua 376 (VL 376), Phule Nachani 1 (KOPN 235), KOPLM 83, Dapoli 1, Dapoli 2
9.	Gujarat	VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), GNN7, GNN 6, GN 5, GN 4
10.	Bihar	VL Mandua 379 (VL 379), Arjuna (OEB-526), VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), RAU 8, VL379, OEB 526, OEB 532
11.	Madhya Pradesh	VL Mandua 379 (VL 379), VL Mandua 376 (VL 376), VL Mandua 352 (VL 352), GPU 28, PR 202

Land preparation

Timely ploughing is advantageous for moisture conservation. In the month of April or May, one deep ploughing with mould-board plough is recommended. Followed by, ploughing with wooden plough twice is necessary. Before sowing, secondary tillage with cultivator using multiple tooth hoe to prepare smooth seed bed is necessary. Minor land smoothening before sowing helps in better *in situ* moisture conservation. Seeds are very small and take 5-7 days to germinate. Hence, good seeds and land preparation helps in better germination, minimize weed problem and effective soil moisture conservation. In Uttaranchal where frequent ploughing operations are difficult to carry out, effective digging and turning of soil, removing perennial weeds, land smoothening, providing inward slope with a shallow drain helps in taking out excess rain water.

Soil and moisture conservation practices

To increase soil quality, summer ploughing or ploughing after the harvest of previous crop. Ploughing can be done across the slope. Erection of small section bunds at an interval of 10-12 m depending on the slope and levelling of the depressions. Opening a dead furrow at 3.3 to 4.0 m interval is required.

Seed rate

Seed rate of 8-10 kg/ha (line sowing) is advised and 4-5 kg/ha (transplanting). A seed rate of 10 kg/ha is found to be optimum for drill sowing and 5 kg/ha for raising seedlings for transplanted condition.

Seed treatment

Seed should be treated with *Thiram* @ 2.5 g/kg of seed to prevent diseases.

Sowing time

Suitable time for sowing is for *Kharif*- June to July, for *Rabi*- September to October. Crop is generally grown during *kharif* season. In certain regions the crop is grown during *rabi* season under irrigated condition.

Method of sowing

Line sowing is beneficial, helps in inter-cultivation and control of weeds effectively. Maintenance of optimum plant population of 4-5 lakh/ha is attained by line sowing using seed drill giving a spacing

of 22.5-30.0 cm between rows and 7.5-10.0 cm between plants. Transplanting is done underirrigated condition.

Nursery management

An area of 150 m^2 is required to raise seedlings for 1.0 ha. Apply 2-3 baskets of well decomposed farm yard mannure (FYM) along with 1.0 kg super phosphate, half kg muriate of potash and half kg ammonium phosphate and 750 g zinc sulphate per bed. Sow the seeds by opening rows at every 3 inch uniformly. Cover the seed with well decomposed FYM and soil/ sand/ water every bed. Top dress with urea 500 g per bed when the seedlings are 12-14 days old. Seedlings of 21-25 days old are ideal for transplanting in rows of 22.5-25 cm with 2 seedlings/hill with 10 cm between hills.

Spacing and fertilizers

In direct sowing spacing between rows should be 22.5 to 30 cm, plant to plant 7.5 cm and depth 3-4 cm. Application of additional quantities of organic matter in soil for finger millet is considered beneficial, since it helps to improve physical condition of soil which helps soil to retain moisture for a longer period of time. Manures are applied 5-10 t/ha FYM about a month before sowing. The crop responds well to fertilizer application. The general recommendation for finger millet is 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per ha under irrigation and 40 kg N, 20 kg P_2O_5 and 20 kg K_2O per ha under rainfed conditions.

State	Spacing (cm)	Fertilizers (N, P_2O_5, K_2O) (kg/ha)	
		Rainfed	Irrigated
Andhra Pradesh & Telangana	22.5 × 10.0	40:20:20	60:30:30
Bihar	22.5 × 10.0	40:20:20	40:20:20
Jarkhand	22.0 × 10.0	40:20:20	40:20:20
Gujarat	30.0 × 7.5	40:20:10	
Himachal Pradesh	25.0 × 10.0	40:20:0	
Karnataka	22.5 to 30 × 7.5 to10 (Rainfed) 22.5 × 10 (Irrigated)	50:40:25	100:50:50
Maharashtra	22.5 × 10.0	25:20:0	50:25:0
Chhattisgarh	25.0 × 15.0	60:30:20	
Madhya Pradesh	22.5 × 10.0	40:40:0	
Orissa	22.5 × 10	40:20:20	60:20:20
Tamilnadu	22.5 × 15.0	40:20:20	90:45:45
Uttaranchal	25.0 × 15.0	60:30:20	

Entire P_2O_5 and K_2O are to be applied at sowing, whereas N is to be applied in two or three split doses depending upon moisture availability.

In areas of good rainfall and moisture availability: 50% of recommended N is to be applied at sowing and the remaining 50% in two equal splits at 25-30 and 40-45 days after sowing.

In areas of uncertain rainfall: 50% at sowing and the remaining 50% around 35 days after sowing is recommended.

Bio-fertilizers

Treating seeds with *Azospirillum brasilense* (N fixing bacterium) and *Aspergillus awamori* (P *Solubilizing* fungus) @ 25 g/kg seed is beneficial. In case seeds are to be treated with seed dressing chemicals, treat the seeds first with seed dressing chemicals and then with bio-fertilizers at the time of sowing.

Procedure for inoculating seeds with bio-fertilizers

Bio-fertilizer culture-specific to the crop is to be used @ 25g/kg of seed. Sticker solution is necessary for effective seed inoculation. This can be prepared by dissolving 25 g jaggery or sugar in 250 ml water and boiling for 5 minutes. The solution thus, prepared is cooled. Smear the seeds well using the required quantity of sticker solution. Then add culture to the seeds and mix thoroughly so as to get a fine coating of culture on the seed. The culture-coated seed is to be dried well in shade to avoid clumping of seeds. Use of the inoculated seeds for sowing can be done.

Irrigation management:

Finger millet is generally grown in *kharif* under rain-fed conditions. If there is any longer dry spell, then irrigation would be required depending on soil type, weather condition and duration of variety. For light soils, irrigate the crop once in 6-8 days, and for heavy soils once in 12-15 days. Under limited irrigation, the crop may be irrigated at critical growth stages like tilling and flowering.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enchinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica*, *Setaria glauca* (bajra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha) and *Sorghum halepanse* (banchari) are common.

Broad-leaved weeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai).

Weed Control

It is essential to control weeds in the initial stage of plant growth and development. The inter-cultivation and weeding should be done with hand hoe at 25 DAS. In line sown crop 2-3 times inter-cultivation and one time hand weeding is suggested. For Broadcast crop two effective hand weeding will minimize weeds. In assured rainfall and irrigated areas, pre-emergence spray with *Isoproturon* @ 0.5 kg a.i./ha. (rainfed areas), *Oxyflurofen* @ 0.1 lit a.i./ha (irrigated areas) can be done. For post-emergence spray 2, 4-D sodium salt @ 0.75 kg a.i./ha around 20-25 days after sowing is recommended.

Inter cropping

State	Crop system
Karnataka, Tamilnadu and Andra pradesh	Finger millet + Pigeon pea in 8-10:2
	Finger millet +Filed bean in 8:1
	Finger millet + Soybean in 4:1
Bihar	Finger millet + Pigeon pea in 6:2
Uttaranchal	Finger millet and Soybean mixed together in 90:10% proportion by weight basis
North hilly areas	Finger millet + Soybean in *kharif* and oats in *rabi* is an ideal remunerative sequence
Maharashtra (Kolhapur)	Finger millet + black gram / moong bean in 6-8:1 (Sub mountain regions)

Crop rotation

Northern states: Rotation with legumes like green gram/black gram/rice bean/soybean is recommended

Southern states: Generally, in southern states horse gram, pigeon pea, field bean or groundnut are used for crop rotation. This practice will minimize inorganic fertilizer application and also give higher yields. Finger millet-finger millet rotation must be discouraged as it affects sustainability of soil as well as crop yield.

Crop sequence

Northern Bihar: Potato-paddy-finger millet cropping sequence is highly remunerative than other cropping sequences for garden land.

Southern Karnataka or Deccan plateau: Finger millet-potato-maize or finger millet-onion-finger millet are highly remunerative cropping sequences.

Assured rainfall areas: raising crop of cowpea or green gram or sesamum followed by sowing/ transplanting of early duration finger millet can be practiced.

Insect pests and their management

Finger millet attracts several pests of which army worm, cutworm, stem borer, leaf aphid, grasshoppers, grey weevil, shoot fly and ear caterpillars are major ones.

Army worms and cut worms

They appear during the early stages and continue up to harvest. 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. In later stages of plant growth, these insects act as defoliators. They are cyclic in nature.

Control

Apply poison baits comprising 10 kg rice bran + 1 kg Jaggery + 1 l *quinolphos* (25% EC). Prepare small balls and broadcast in the fields preferably in the evening time.

Leaf aphid

It occurs throughout the crop growing period. The nymphs and adults suck the sap from tender leaves and stem. They can cause serious damage in the seedling stage up to 30 days.

Control

Spraying of *Dimethoate* 30 EC @ 1.5 ml/liter of water gives effective control.

Stem borer

The larva bores into the stem, resulting in dead heart.

Control

Spraying the crop with *Metasystox* 25 EC @ 2 ml/liter of water helps in control of borer.

Earhead caterpillars

Earhead caterpillars appear at 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. This further attracts saprophytic fungi.

Control

Dust *Malathion* 5% @ 24 kg/ha or *Quinolphos* 1.5% @ 24 kg/ha.

Diseases and their management

Blast (*Pyricularia grisea*)

Typical blast lesions are diamond shaped with grey center and dark margin appear on the leaf. Any part of plant including leaves, peduncle and grains can be infected. Grains of infected earheads are shrivelled and become light in weight.

Control

It can be controlled by growing resistant varieties. Treat the seeds with fungicides like *Carbendazim* @ 2g/kg seed a day before sowing. If necessary, spray the nursery with *Carbendazim* (0.1%) or *Tricyclazole* (0.1%). Spray any of the above advised fungicides at flowering stage and repeat 10 days later to control neck and finger blast.

Brown spot

Small and medium size brown to dark spot appear on the leaf, leaf sheath, and other plant parts. Damage could be severe if the crop is subjected to drought or nutrition deficiency.

Control

The disease can be effectively managed by proper nutrition and water management. Need-based spraying of *Mancozeb* (0.2%) can be applied.

Harvesting

The crop matures in about 95 to 110 days in case of early varieties and 115 to 125 days in case of medium to late duration varieties depending on the region and the variety. The ear heads are harvested with ordinary sickles and straw is cut close to ground. At some places under rainfed condition, the whole plant with ear head is cut, heaped and then threshed.

Yield

It is possible to harvest 25-30 q/ha of grain under well managed conditions and 60-70 q/ha of fodder. The straw of finger millet makes nutritious fodder and it is preferred over paddy straw. It can be preserved by putting up in well-built stacks.

8. Foxtail millet

(Setaria italica L.)

Common name: *Kakun*

Vernacular names: *Kangni, Kakum (Hindi), Kang, Rala (Marathi), Navane (Kannada), Korra (Telugu), Keppai, Thenai (Tamil), Kaon (Bengali), Kang (Gujrati), Kanghu, Kangam, Kora (Oriya), Kangani (Punjabi)*

Climate and soil

Foxtail millet can be grown in tropics as well as sub-tropical regions both under low and moderate rainfall. The crop can be grown in altitude upto 2000 m with 50-75 cm annual rainfall. Foxtail millet grows well on well-drained loamy soils. They will not tolerate water-logged soils or extreme drought.

Improved varieties: The list of latest and popular varieties recommended for different states are given below.

Sl. No.	State	Varieties
1.	Andhra Pradesh and Telangana	SiA 3088, SiA 3156, SiA 3085, Lepakshi, SiA 326, Narasimharaya, Krishnadevaraya, PS 4
2.	Karnataka	DHFt 109-3, HMT 100-1, SiA 3156, SiA 3088, SiA 3085, SiA 326, PS 4, Narasimharaya,
3.	Tamilnadu	CO (Ten) 7, TNAU 43, TNAU-186, TNAU 196, CO 1, CO 2, CO 4, CO 5, K2, K3, SiA 3088, SiA 3156, SiA 3085, PS 4
4.	Rajasthan	Prathap Kangani-1 (SR 51), SR 11, SR 16 (Meera), SiA 3085, SiA 3156, PS 4
5.	Uttar Pradesh	PRK 1, PS 4, SiA 3088, 3085, Sreelaxmi, Narasimharaya, SiA 326, S-114
6.	Uttarakhand	PS 4, PRK 1, Sreelaxmi, SiA 326, SiA 3156, SiA 3085
7.	Bihar	RAU-2, SiA 3088, SiA 3156, SiA 3085, PS 4

Land preparation

Before the onset of monsoon, the field should be ploughed once with mold board plough. With onset of monsoon the field should be harrowed or plough with local plough twice in northern India or with blade harrows in south India.

Season

Season differs from state to state based-on environmental conditions. In Tamilnadu it is in July, July-August in Karnataka, first fortnight of July in Andhra Pradesh and Telangana, second and third week of July in Maharashtra. In Tamilnadu, *kharif* irrigated crop is planted from the beginning of June to end of July and *rabi* crop in August to September, and summer irrigated crop in January. In plains of Uttar Pradesh and Bihar it is middle of June.

Seed rate

For line sowing recommended seed rate is about 8-10 kg/ha and for broadcasting 15 kg/ha is recommended.

Seed treatment

Seed should be treated with Ceresan @ 3 g/kg of seed to prevent diseases.

Method of sowing: Line sowing or broadcasting.

Spacing

Row to row 25-30 cm, plant to plant 8-10 cm and sowing depth 2-3 cm.

Fertilizers

The crop is usually manured with 5 to 10 t/ha farm yard mannure (FYM) about a month before sowing. Generally, fertilizer recommendations to get a good crop are 40 kg N, 20 kg P_2O_5 and 20 kg K_2O/ha. Apply entire quantity of phosphorus P_2O_5 and half of N at sowing and remaining half of N at 30 days after sowing. Fertilizer recommended for different states is as below.

State	Fertilizer recommended NPK (kg/ha)
Andhra Pradesh & Telangana	40:30:0
Jharkhand	40:20:0
Karnataka	30:15:0
Maharashtra	20:20:0
Tamilnadu	40:20:0
Other regions	20:20:0

Water management

Foxtail millet sown during *kharif* season does not require any irrigation. However, if dry spell prevails for longer period, then first irrigation at 25-30 DAS and second irrigation at 40-45 DAS must be given to boost the yields.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica*, *Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari) are common.

Broad-leavedweeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai).

Weed control

Two inter cultivations and one hand weeding in line sown crop is recommended for better yields. Two hand weeding in broadcast crop and post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS should be done. Isoproturon @ 1.0 kg a.i./ha as pre-emergence spray is also effective for weed control.

Inter cropping

Foxtail millet + groundnut (2:1 ratio), foxtail millet + cotton (5:1 ratio) and foxtail millet + pigeon pea (5:1 ratio) are recommended.

Relay cropping

If monsoon is early, sow foxtail millet at 45 cm row spacing and introduce *rabi* sorghum as relay crop when foxtail millet is nearing maturity.

Sequence cropping

Foxtail millet-mustard, foxtail millet-green gram, foxtail millet-pigeon pea and foxtail millet-sunflower are profitable than sole crop of foxtail millet.

Insect-pests and their management

Shoot fly and its control

Apply *Carbofuran* 3G granules @ 20 kg/ha in furrows or as broadcast before sowing in the soil at the time of field preparation.

Diseases and their management

Downy mildew

Diseased plants are dwarfed with excessive development of tillers. Length-wise yellow-green strips are seen on the leaves.

Control

Removal of crop residies from the field. Fungicidal seed treatment or spray of Ridomil-MZ @ 3 g/lit water control the disease.

Rust

Small, numerous blister like pustules observed first on the lower leaves and later on the upper leaves.

Control:

Foliar spray of Mancozeb @ 0.2% effectively controls the rust.

Harvesting time

The crop matures in 80-100 days depending on the variety. The crop is harvested when the earheads are dry, either by cutting the whole plant by sickle or the ears separately.

Yield

Grain 20-25 q/ha and Straw 30-40 q/ha.

9. Little millet

(Panicum sumatrense L.)

Common name: *Kutki*

Vernacular names: *Kutki, Shavan* (Hindi), *Sava, Kutki* (Marathi), *Same, Save* (Kannada), *Samalu* (Telugu), *Samai* (Tamil), *Sama* (Bengali), *Gajro, Kuri* (Gujarati), *Suan* (Oriya), *Swank* (Punjabi)

Climate

Little millet is originated in south-east Asia and is grown throughout India. Important states are Madhya Pradesh, Orissa, Jharkhand, Uttar Pradesh, Chhattisgarh, Tamilnadu and Karnataka. It can withstand both under drought and water logging. It can be cultivated up to 2000 m above mean sea level.

Improved varieties: The list of latest and popular varieties recommended for different states are given below.

S. No.	State	Varieties
1.	Orissa	Chhattisgarh Kutki 1 (BL-6), OLM 203, OLM 208, OLM217, DHLM36-3, DHLM14-1
2.	Madhya Pradesh	Chhattisgarh Kutki 1 (BL-6), Jawahar Kutki 4 (JK 4), JK 8, JK 36, JK137, DHLM 36-3
3.	Andhra Pradesh & Telangana	Chhattisgarh Kutki 1 (BL-6), DHLM 36-3, OLM 203, JK 8
4.	Tamilnadu	Chhattisgarh Kutki 1 (BL-6), DHLM 14-1, DHLM 36-3, Paiyur 2, TNAU 63, CO 3,CO4,K1, OLM203, OLM 20
5.	Chattisgarh	Chhattisgarh Kutki 1 (BL-6), Chhattisgarh Kutki2 (BL-4), JK 8, JK137, JK 36, DHLM 36-3
6.	Karnataka	DHLM 36-3, DHLM 14-1, Chhattisgarh Kutki 1 (BL-6), OLM 203, JK 8
7.	Gujarat	GNV-3, Chhattisgarh Kutki 1 (BL-6) GV 2, GV 1, OLM 203, JK 8, DHLM 36-3, DHLM 14-1
8.	Maharashtra	Chhattisgarh Kutki 1 (BL-6), Phule Ekadashi (KOPLM 83), JK 8, OLM 203, DHLM 36-3, DHLM 14-1
9.	Jharkhand	Chhattisgarh Kutki 1 (BL-6), DHLM 36-3

Seed rate

Optimum seed rate is 6-8 kg/ha for line sowing and for broadcasting 10-12 kg/ha is required.

Seed treatment

Seed treated with Ceresan @ 3 g/kg of seed and seed inoculation with *Agrobacterium radiobacter* and *Aspergillus awamori* improve seed yield.

Sowing time

Suitable time for *Kharif* is June to July. In certain parts of the country the crop is also sown during September-October (*Rabi*).

Season

In Orissa - Middle of June; in Tamilnadu - June and September-October; in Karnataka, Madhya Pradesh and South Bihar - last week of June to first week of July is desirable to escape from shoot fly and gall midge infestation.

Method of sowing

Broadcasting and line sowing.

Spacing

Spacing of row to row is 22.5 cm, plant to plant is 8-10 cm and sowing depth is 3 cm is recommended.

Manures and fertilizers

5-10 t/ha farm yard manure (FYM) could be applied about a month before sowing. In addition, application of 40 kg N, 20 kg P_2O_5 and 20 kg K_2O per hectare is recommended. The fertilizer dose adopted in different states is as follows:

States	$N:P_2O_5:K_2O$ (kg/ha)
Andhra Pradesh& Telangana	20:20:0
Bihar and Orissa	20:10:0
Tamilnadu	40:20:0
Other states	20:20:0

Bio-fertilizer

Seed inoculation with *Agrobacterium radiobacter* and *Aspergillus awamori* improves seed yield.

Water management

A minimum of 3 to 4 irrigations are required for good plant stand and optimum yield. Under limited water availability, the crop may be irrigated at 30-40 days after sowing and second at seed filling stage which can be adopted especially, in early maturity varieties (75-85 days).

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusineindica*, *Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari) are common.

Broad-leavedweeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai).

Weed control

Two inter-cultivation and one hand weeding in line sown crop and two hand weeding in broadcast crop are necessary for effective weed control. Post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS and Isoproturon @ 1.0 kg a.i./ha as pre-emergence spray is also effective in weeds control.

Inter cropping

In different state it is in different combinations. In Orissa it is Little millet + black gram in 2:1 row ratio; Madhya Pradesh Little millet + Sesamum /soybean/pigeon pea in 2:1 row ratio and in Southern Bihar- Little millet + pigeon pea in 2:1 row ratio.

Cropping sequence

In South Bihar, little millet followed by niger is being followed.

Insect-pest and their management

Shootfly

It is the most serious pest causing significant yield losses. Early sowing with the onset of monsoon is an effective and cheapest method of its control.

Stem borer

Apply Carbofuran 3G @ 20 kg/ha in the soil at the time of field preparation.

Termites

Use Methyl parathion (2%) dust @ 20-25 kg/ha before sowing.

Diseases and their management

Though, there are no serious diseases on this crop, grain smut may be problematic sometimes, which is effectively checked by pre-sowing treatment of the seeds

Smut

The affected earheads are full of black masses covered with a thin yellow membrane.

Control

Soaking seeds in hot water at 55 ^{o}C for 7-12 minutes followed by drying kills the seed-borne pathogen. Seed treated with *Thiram* @ 2.5 g/kg seed or Carboxin @ 2g/kg seeds can also be practiced.

Harvesting time

Kharif season crop- September to October and for Rabi- January to February at the maturity.

Yield

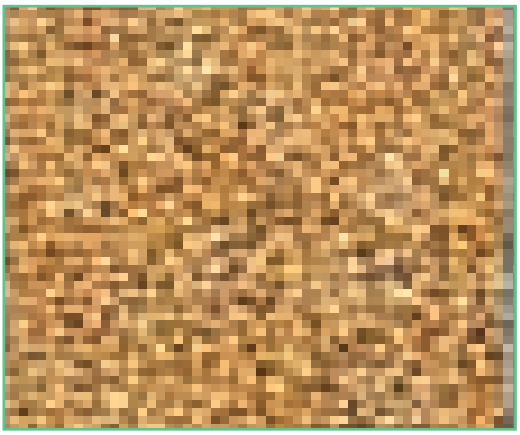
Grain yield is 15-20 q/ha and Straw 20-25 q/ha under well managed crop conditions.

10. Proso millet

(Panicum miliaceum L.)

Common name: *Chena, Common Millet, Brown-corn millet*

Vernacular names: *hena, Barri* (Hindi), *Vari* (Marathi), *Baragu* (Kannada), *Variga* (Telugu), *Pani Varagu* (Tamil), *Cheena* (Bengali), *Cheno* (Gujrati), *Bacharibagmu* (Oriya), *Cheena* (Punjabi).



Climate

Proso millet is cultivated during kharif and summer in India. It is highly drought resistant and can be grown in areas where there is scanty rainfall. It can withstand water stagnation also to some extent. It is a hardy crop which completes its life cycle in a short span of time.

Soil

Proso millet can be grown both in rich and poor soils, having variable texture, ranging between sandy loam to clays of black cotton soils. Coarse sands are not suited for proso millet cultivation. Well drained loam or sandy loam soils free from *stones* and gravels, better water holding capacity with high organic matter are ideal for proso millet cultivation.

Improved varieties: The list of latest and popular varieties recommended for different states are given in the Table below.

State	Varieties
Tamilnadu	ATL 1 (TNPm 230), Co5, TNAU 151, TNAU 164, TNAU 145, TNAU 202, CO 4, K2, CO 3,CO 2, GPUP 21, GPUP 8
Uttarakhand	PRC 1, TNAU 145, TNAU 164, TNAU 151
Karnataka	ATL 1 (TNPm 230), DHPM-2769, GPUP 8, GPUP 21, TNAU 145, TNAU151, TNAU 164, TNAU 202
Bihar	ATL 1 (TNPm 230), BR 7, TNAU 164, 145, PR 18, TNAU 202
Andhra Pradesh& Telangana	TNAU 202, TNAU 164, TNAU 151, Sagar, Nagarjuna, CO 4, CO 3, TNPm230
Uttar Pradesh	Bhawna, PRC 1, TNAU 145, 164, 151
Madhya Pradesh	TNAU 202
Chattisgarh	TNAU 202
Gujarat	TNAU 202

Field preparation

Soon after harvesting of the previous crop, the field should be ploughed to expose the soil to sun and enable it to retain more moisture. With onset of monsoon, the land should be harrowed two or three times and then finally leveled. When it is being grown during summer, one irrigation should be given prior to land preparations. As soon as the soil comes in the working conditions, the seedbed should be prepared by running harrow or desi plough thrice followed by planking. Proso millet needs a finely tilted clean seedbed but does not respond to deep ploughing, since the crop has shallow root system.

Seed and sowing

For shoot fly control seed treatment with thiamethoxam 25 WDG @4 g/Kg may be done.

Season

The rainy season crop is sown in onset of monsoon preferable in July. September –October in Tamilnadu and Andhra Pradesh, mid-March, mid-May in Bihar and Uttar Pradesh as irrigated catch crop. It is chiefly grown in central and eastern Uttar Pradesh, western Bihar, North Eastern states and Andhra Pradesh.

Time of sowing

As a *kharif* crop, proso millet should be sown in the first fortnight of July with the onset of monsoon rains and as a summer crop, it should be sown by the Feb/March. During summer, it would be desirable to sow proso millet as soon as the harvesting of the *rabi* crop is harvested.

Method of sowing

Proso millet can be sown by broadcasting or line sowing using seed drills in furrows 3-4 cm deep.

Spacing

Row to row distance should be kept 22.5 cm and plant to plant 10 cm. Line sowing ensures better germination, cuts down seed requirement and facilitates intercultural operations compare to broadcast sowing.

Seed rate

Recommended seed rate is 10 kg/ha for line sowing and for 15 kg/ha^{-1} broad casting.

Manures and fertilizers

Proso millet being a short duration crop, requires relatively less amount of nutrients compared to other cereals. To get a good crop, general fertilizer recommendations under irrigated condition are 40-60 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha. Apply half of the N and whole amount of phosphorus and potash as a basal dose at the time of sowing. The remaining half of N should be applied at the time of the first irrigation. Under rainfed condition, fertilizer dose is reduced to half of the irrigated crop. If organic manure is available, it may be added to the soil about a month before sowing at the rate of 4 to 10 tons per hectare. Fertilizer required for different states is as mention below.

States	Fertilizer recommended NPK (kg/ ha)
Andhra Pradesh&Telangana	20:20:0
Bihar and Tamilnadu	20:10:0
Uttar Pradesh	40:20:0
Other states	20:20:0

Water management

Proso millet sown during *kharif* season, generally does not require any irrigation. However, at tillering stage, if dry spell prevails for longer period, one irrigation must be given to boost yields. Summer crop, however, would require two to four irrigations depending upon soil type and climatic conditions. Give first irrigation 25-30 days after sowing and second irrigation about 40-45 days after sowing. Due to shallow root system of proso millet, heavy irrigation is not advisable.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusineindica*, *Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari)

Broad-leavedweeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai)

Weed control

Hand weeding may be done for removal of broad-leaf weeds.

Cropping system

In Bihar and Uttar Pradesh generally, intercropping of Proso millet + green gram in 2:1 ratio is in practice and in Western Bihar, Potato - Proso millet cropping sequence is profitable.

Insect-pests and their management

Shoot fly

Shoot fly is the most serious pest of proso millet causing significant yield losses.

Management

Early sowing with the onset of monsoon is an effective and cheapest method of control. Use seeds treatment with thiamethoxam 25 WDG @4 g/Kg of seed. Apply Carbofuran (Furadon) 3G granules @ 20 kg/ha in furrows before sowing.

Diseases and their management

Head smut

Head smut is a common disease of proso millet. The affected panicles become elongated and thickened. The smut masses rupture before harvest.

Management

Treating seeds with organo-mercurial compounds like Ceresan at the rate of 3g/kg of seed or hot water treatment (soaking seeds in hot water at 55˚C for 7-12 minutes) will reduce incidence.

Harvesting and threshing

Proso millet is ready for harvest after 65-75 days of sowing in most of the varieties. Harvest the crop when it is about to mature. The seeds in the tip of upper heads ripe and shatter before the lower seeds and later panicles get matured. Therefore, the crop should be harvested when about two thirds of seeds are matured. Crop is threshed with hand or bullocks.

Yield

With improved package of practices, it is possible to harvest 20-23 q of grain and 50-60 q of straw per hectare under irrigated condition and 10-15 q grain and 30-40 q of fresh straw per ha under rainfed condition.

11. Kodo millet

(PaspalumscrobiculatumL.)

Common name: Kodo

Vernacular names: *Kodon* (*Hindi*), *Kodra* (*Marathi*), *Harka* (*Kannada*), *Arikelu, Arika* (*Telugu*), *Varagu* (*Tamil*), *Kodo* (*Bengali*), *Kodra* (*Gujrati*), *Kodua* (*Oriya*), *Kodra* (*Punjabi*)

Climate

Kodo millet is grown mostly in warm and dry climate in India. It is highly drought tolerant and therefore, can be grown in areas where rainfall is scanty and erratic. It thrives well in areas receiving only 40 to 50 cm annual rainfall.

Soil

Kodo millet is grown from gravelly and stony upland poor soils to loam soils. Deep, loamy, fertile soils, rich in organic matter, are ideal cultivation condition for higher profit. Well-drained soils with adequate moisture supply are required for uninterrupted growth of the crop.

Improved varieties: The list of latest and popular varieties recommended for different states are given below.

State	Varieties
Madhya Pradesh	JK 439, JK 137, JK 106, JK98, JK 65, JK 48, JK 13, RBK 155, RK 390-25, GPUK 3, DSP9-1, TNAU86
Tamilnadu	KMV 20 (Bamban), CO 3, TNAU 86, GPUK 3, RK 390-25
Gujarat	GK 2, GK 1, GPUK 3, JK65, JK13, RK 390-25
Chattisgarh	Chhattisgarh Kodo-2, Jawahar Kodo137 RBK 155,Indira Kodo 48, Indira Kodo1, GPUK 3, JK 439, JK98, JK 65, Chhattisgarh-2, RK 390-25, TNAU 86
Karnataka	GPUK 3, RBK 155, RK 390-25, TNAU86
Andhra Pradesh & Telangana	RK 390-25, TNAU 86

Seed rate

Optimum seed rate for line sowing is 10 kg/ha and for broad casting is 15 kg/ha.

Seed treatment

Seed treated with Ceresan @ 3 g/kg of seed is recommended.

Sowing time

Suitable sowing time for *Kharif* is June to July.

Season

Sowing with onset of monsoon is beneficial for best yields. Middle of June to end of July in different states and in Madhya Pradesh and Chattisgarh, it is last week of June to first week of July.

Method of sowing

Broadcasting or line sowing is recommended.

Spacing

Spacing between rows is 22.5 cm and between plants is 10 cm and depth 3-4 cm. Line sowing is beneficial as it facilitates inter-cultivation and weed management.

Manures and fertilizers

Addition of organic manures is always beneficial, it helps to improve the water retention capacity of soil in addition to providing essential nutrients to the crop plants. The crop should be manured with 5-10 t/ha FYM about a month before sowing. Apply 40 kg N, 20 kg P_2O_5 and 20 kg K_2O per hectare. All the fertilizers may be applied at the time of sowing in furrows. In high rainfall areas of Madhya Pradesh and Chattisgarh, N should be applied in 2 splits i.e. half at sowing and remaining half at 35-40 days after sowing.

Bio-fertilizers

Treating seeds with *Azospirullum brasilense* (nitrogen fixing bacterium) and *Aspergillus awamori* (phosphate solubalizing fungus) @ 25 g/kg is beneficial. The procedure for incorporating seeds with bio-fertilizer as given for finger millet can be followed.

Irrigation management

During dry periods, irrigations are required every 4-7 days depending on the severity of the drought and type of soil. In case of limited irrigation facility first irrigation can be given at 25-30 DAS and second irrigation at 40-45 DAS. Drain out the excess rain water from the field during heavy and continuous rains.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusineindica* ,*Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari) are common.

Broad-leaved weeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai).

Weed control

It is essential to control weeds in the initial stages of plant growth. Generally, two weeding at an interval of 15 days are sufficient. Weeding may be done with hand hoe or wheel hoe in line sown crop.

Hand weeding should be done twice around 20 and 35 days after sowing and 2-3 inter cultivations are to be done. In assured rainfall areas of Madhya Pradesh, pre-emergence application of Isoproturon @ 0.5 kg a.i./ha is also effective in control of weeds. Post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS controls broad leaved weeds.

Intercropping

In Madhya Pradesh, it is recommended to adopt Kodo millet + Pigeon pea in 2:1 ratio for intercropping. It is also advised to practice Kodo millet + Green gram/black gram combination in 2:1 ratio and Kodo millet + Soybean in 2:1 ratio for intercropping.

Crop rotation and cropping sequence

Kodo millet – soybean or kodo millet – kodo millet or niger-kodo millet crop was found to be sustainable system in Madhya Pradesh.

Insect-pests and their management

Shoot fly

This is the only serious pest and appears 10 days after sowing resulting in dead hearts. It can cause significant yield losses in years of serious incidence.

Management

Apply *Carbofuran*3G granules @ 20 kg/ha in furrows before sowing.

Delayed sowing increases shoot fly incidence. Sowing with the onset of monsoon is beneficial. Sow the crop before 2nd fortnight of July. In case of delayed sowing, adopt higher seed rate (1½ times the recommended seed rate) and need-based application of insecticides is must.

Termites and stem borer

These are two major insect pests of kodo crop. Termites may be controlled by applying *Malathion* 5% dust @ 20-25 kg per hectare dust in the soil before sowing.

Disease and their management

Rust

Brown pustules are seen on leaves. This disease hinders photosynthesis and cause considerable loss in yield.

Control

Controlled to some extent by spraying of 0.2% solution of Mancozeb 75 WP.

Head smut

This is seed born disease. The affected earheads are full of black masses covered with a thin yellow membrane.

Control

Growing of tolerant cultivar like GPUK 3 in disease prone areas. Seed treatment with *Thiram* @ 2.5 g/kg of seed and soaking seeds in hot water at 55 ^{o}C for 7-12 minutes.

Harvesting

In *Kharif* season, the crop becomes ready for harvest in the month of September or October in northern India.

Yield

With improved package of practices, one can obtain 15-18 q grain and 30-40 q straw per ha.

12. Barnyard millet

(Echinochloa frumentacea L.)

Common name: Sawan

Vernacular names: *Sanwa, Jhangora* (*Hindi*), *Bhagar* (*Marathi*), *Oodalu* (*Kannada*), *Udhalu, Kodisama* (*Telugu*), *Kuthiraivali* (*Tamil*), *Shyama* (*Bengali*), *Khira* (*Oriya*), *Swank* (*Punjabi*)

Adaptation

Barnyard millet is quite popular in northern hills up India especially in the foot hills up Himalayas. It is important component of hill and tribal agriculture. It is also grown on a lesser scale in Bihar, Tamilnadu, Maharashtra and Madhya Pradesh.

Plant type

Plant of barnyard millet is tall, erect up to 50-95 cm in height. Its leaves are flat, glabrous or slightly hairy without ligule. The grain is caryopsis and white or yellow in colour.

Improved varieties: The list of latest and popular varieties is given below.

State	Varieties
Uttarakhand	VL 172, VL 207, PRJ 1, VL 29, PRS 1, DHBM93-3
Uttar Pradesh	VL 172, VL 207, Anurag, VL 29, DHBM 93-3, Kanchan
Tamilnadu	MDU-1, DHBM93-3 , DHBM23-3 , CO 1, CO 2, VL 181, VL 29
Karnataka	VL 172, RAU 11, VL 181, DHBM 93-3, DHB 93-2, DHBM23-3
Gujarat	Gujarat Banti1, DHBM93-3, VL172
Bihar	VL Madira 181, DHBM93-3
Andhra Pradesh& Telangana	DHBM93-3, DHBM23-3
Madhya Pradesh	DHBM93-3, DHBM23-3

Seed rate

Optimum seed rate is 8-10 kg/ha in line sowing and 15 kg/ha for broadcasting.

Seed treatment

Seed should be treated with Ceresan @ 3 g/kg of seed.

Season

In Tamilnadu, it is September–October in rainfed areas and, February–March in irrigated lands; in Uttaranchal and North Eastern States, it is April-May. Dry seeding prior to the onset of monsoon is practiced in hills.

Sowing time

For *Kharif* season, it is June to July and for *Rabi* season, it is September to October.

Method of sowing

Broadcasting and line sowing is recommended.

Spacing

Row to row 25 cm, plant to plant 10 cm and depth 3-4 cm is recommended.

Manures and fertilizers

Manures: 5-10 t/ha FYM could be applied about a month before sowing. Fertilizers: 40 kg N, 20 kg P_2O_5 and 20 kg K_2O per hectare. Fertilizer required for different states is as follows.

States	Fertilizer recommended (NPK) (kg/ha)
Andhra Pradesh& Telangana	20:20:0
Bihar and Tamilnadu	40:20:0
Uttar Pradesh	40:20:0
Other states	20:20:0

Bio-fertilizer

Inoculating seeds with *Agrobacterium radio-bacter* and *Aspergillus awamori* is recommended.

Water management

Generally, barnyard millet does not require any irrigation. However, if dry spell prevails for a longer period, then one irrigation at 25-30 DAS and second irrigation at panicle initiation stage 45-50 (DAS) can be given.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusineindica* ,*Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari) are common.

Broad-leaved weeds: *Celosia argentia* (chilimil), *Commelina benghalensis* (kankoua), *Phylanthus niruri* (hulhul), *Solanum nigrum* (makoi) and *Amaranthus viridis* (chaulai).

Weed Control

Two inter cultivations and one hand weeding in line sown crop should be done. Two hand weeding should be done in broadcast crop. Post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS and Isoproturon @ 1.0 kg a.i./ha as pre-emergence spray is also effective in weed control.

Cropping system

Barnyard millet + rice bean in 4:1 row ratio is recommended for Uttaranchal.

Insect-pests and their management:

Shoot fly

Shoot fly is the most serious pest causing significant yield losses. Early sowing with the onset of monsoon is an effective and cheapest method of control.

Stem borer

Apply Carbofuran 3G @20 kg/ha in the soil at the time of field preparation.

Termites

Soil should be mixed with *Chlorphyriphos* 5D@35 kg/ha at the time of sowing. When the incidence of pest is noticed in standing crop dilute *Chlorphyriphos* 20EC in 5 lit of water and mix it with 50 kg of soil and broadcast evenly in one ha followed by light irrigation. Use *Methyl parathion* (2%) dust @ 20-25 kg/ha before sowing.

Diseases and their management

Smut

The crop although affected by three different smuts, the grain smut is important.

Management

Seed treated with thiram @ 2.5 g/kg of seed and soaking seeds in hot water at 55 °C for 7-12 minutes is done.

Harvesting

The crop should be harvested when the panicle dries. It is cut from the ground level with the help of sickles and stacked in the field for about a week. Threshing is done by trampling under the feet of bullocks or any suitable threshing machine.

Yield

Grain yield of 12-15 q/ha and Straw: 20-25 q/ha can be obtained.

13. Brown-top Millet

(Panicum ramose L.*)*

Common name: *Dixie signalgrass*
Scientific names: *Brachiaria ramosa* (L.) Stapf; *Panicum ramosum* L
Vernacular names: *Korale* (Kannada), *Andukorralu* (Telugu)

Adaptation

Brown-top millet is grown in rocky, shallow soils from sea level up to 2500 mabs. It is adaptable to almost all upland soil, but does not grow well in water-restricted, drought conditions. It will not survive in temperature less than 11°C. This millet seed is grown in a variety of soils and climates. Like other millets, it is a hardy crop and well suited for dryland.

Improved variety

S. No.	State	Variety
1.	All states	IIMR AK 2

Planting time

Brown-top millet can be planted from mid April until mid August in most locations, though late plantings will result in lower yields.

Seed rate and planting

The seed rate for brown-top millet will depend upon both the reason (birds & wild life) and the seedling method. When planted in rows seed rate of 5 kg/ha is sufficient. Seed should be covered superficially in a firm seed bed. This method is recommended for a better yield. Seeds get germinate by the fifth day of sowing.

Intercropping

The species commonly planted intercropping with brown-top are sunflowers, maize, sorghum, soybean, and peas. It can also be intercropped in a tree orchard.

This method is ideally suited to larger fields, in which the millet is planted in alternating strips with other crops.

Fertilizer

Fertilization with phosphorous and nitrogen can help increase forage productivity; rate of application should be determined on the basis of soil tests and /or country recommendations.

Weed management

To control weeds, it is best to plant in a well-tillage field, weed-free bed with narrow row spacing. Chemical weed control options are limited. It does not regrow well after cutting, so it is a single–cut crop.

Insect-pests and their management

Shoot fly, Army worms and grasshoppers are very common pests to this crop.

Diseases

Rust

Rust is observed in peninsular India like Karnataka and Tamilnadu. Many small pustules appear on leaves and damage photosynthetic area.

Control

Foliar spray of Mancozeb @ 0.2% effectively controls the rust.

Crop maturity

The crop matures within 90-100 days.

Yield

Seven to eight quintal grains per acre (1.7 to 2.0 t/ha) and four tractor loads of (4.0 t/ha) good quality fodder can be obtained.

Seed processing

The cultivation of brown-top is simple but processing is difficult due to the hard-outer cover of the seed. As a result, farmers get only 40-50 kg of rice from one quintal of brown-top seeds. Earlier grinding stones were used to separate the grain from the seed.

14. Primary processing technologies for millets

After harvesting, grains of cereals or coarse cereals are not eaten as uncooked whole seeds in any human society. Millets are good sources of calorie and nutrients. There is raising demand for millets is leading to higher prices and requirement of quality grains, can make their cultivation profitable and sustainable. The focus on utilization of millets is on an upward swing given the proven understanding that they are good source of phytochemicals and dietary fiber.

Need for processing of millets

In general, primary operation in processing of cereal or coarse cereal is usually the separation of dirt material, pericarp and sometimes the germ from the edible portion. The outer tough seed coat of millets, characteristic flavour, cultural attachments and non-availability of processed millet products are limiting factors unlike rice or wheat. These are the prime reasons for less popularity of millet foods among rice and wheat eaters. The farmers are getting very less price (Rs.15-20/kg) to their un-processed produce compared to processed one (Rs.80-100/kg). Unfortunately, there is no well-proven industrial process available for making white products from coloured small millets satisfactory. The nutrients composition and technological properties of small millet grains offer a number of opportunities for processing and value-addition to use as next generation foods to satisfy the consumers' choice of different culture, location, choice and society.

Advantages of millets processing

Digestibility	Processing is required to make dried grains edible and digestible
Food safety	Cooking inactivates natural toxins and heat prevents bacterial and food spoilage
Organoleptic properties	Processing optimizes the appearance, taste and texture of foods to meet the needs of consumers
Ready to eat (RTE) and convenience	To meet consumer demand for quick and easy meal solutions and also nutritional supplement
Maximize nutritional availability	Processing can make it easier for nutrients from grains to be digested. Nutrients lacking in the diet can be added to staple grain-based foods (food fortification) (e.g. thiamin added to flour)

Primary processing methods

Millets have good grain qualities for processing. Primary processing mainly involves destoning, cleaning, dehusking, dehulling, grading and pulverizing. Millets can be used for traditional as well as novel value-added foods. Unprocessed or processed grain can be cooked as whole or decorticated and if necessary, ground to flour by traditional or industrial methods. However, there is a need to look into the possibilities of alternative uses.

De-cortication

De-cortication is partial removal of outer layer of the millet grain. It is accomplished by hand pounding and using rice de-hulling or other abrasive de-hullers.

Pounding

Traditionally, dry, moistened or wet grain is pounded with a wooden pestle in a wooden or stone mortar. Moistening the grain by adding about 10% of water facilitates not only the removal of fibrous

bran but also the separation of germ and endosperm, if desired. However, this practice produces slightly moist flour. Parboiling increases the de-hulling efficiency of kodo millet and also eliminates stickiness in cooked finger millet porridge.

In hand pounding, grain which should be fairly dry, is crushed and pulverized by the backward and forward movement of the hand-held stone on the lower stone. Generally, women do these unpleasant and laborious work. It has been reported that women working hard with a pestle and mortar can decorticate 1.5 kg per hour providing a non-uniform poor keeping quality product.

De-hulling

De-hulling is accomplished by using rice de-hullers or other abrasive de-hullers. Millets would probably be more widely used if processing is improved. In market, many machines are available for processing of cereals.

Nutrient composition of whole sorghum grain and pearled sorghum grain (per 100g)

S. No	Parameters	Whole grain	Pearled grain
1.	Moisture (%)	11.90	10.00
2.	Ash (%)	1.60	1.70
3.	Protein (%)	10.40	6.56
4.	Fat (%)	1.90	1.10
5.	Carbohydrates (%)	72.60	76.15
6.	Iron (mg)	4.10	2.90
7.	Calcium (mg)	25.00	12.09
8.	Zinc (mg)	1.60	1.10
9.	Riboflavin (mg)	0.13	0.80
10.	Energy (KCal)	349	340

Source: Dayakar et al, 2018. Nutritional and health benefits of nutri-cereals. ICAR-IIMR Hyderabad. pp 96.

Benefits of de-hulling in millets

Wheat has the unique property of forming an extensible, elastic and cohesive mass when mixed with water. Millet flours lack these properties when used alone. Hence, fortification brings many innovative 'Ready-to-Eat and Ready-to-Serve' millet based processed products. Processing makes possible to fortify malted finger millet (70%) weaning food with green gram (30%) having low cooked paste viscosity and high energy density.

The de-cortication reduces total protein and lysine by 9% and 21%, respectively, but improves the remaining protein utilization. The loss of minerals is minimal. Decortication improves the biological availability of nutrients and consumer acceptability. The phytate content of proso millet varieties ranged from 170 to 470 mg/100 g whole grain, and dehulling resulted in a 27 to 53% reduction in phytate content.

Major millet dehuller

On de-hulling, phytin phosphorus decreased by 12% in proso millet, 39% in little millet, 25% in kodo millet and 23% in barnyard millet. De-hulling of sorghum can remove 40 to 50% of both phytate and total phosphorus. Bio-availability of iron in sorghum in human subjects was found to reduce more by phytin phosphorus thereby tannin content of the grains. On pearling of sorghum grain, a significant increase in ionizable iron and soluble zinc content showed improved bioavailability of these two micronutrients, which was attributed partially to the removal of phytate, fibre and tannin along with the bran portion during pearling.

Millet mill dehuller - Type I

Millet mill dehuller - Type II

Destoner-cum-Grader-cum-Aspirator

Millet pulverizer

Small millets polisher

Proximate composition of different sorghum value-added products compared to flour

Name of product	Moisture (g)	Protein (g)	Fat (g)	Total fiber (g)	Insoluble dietary fiber(g)	Soluble dietary fiber (g)	Carbo-hydrates (g)	Energy (K. Cal)
Sorghum flour	13.80	6.20	2.80	9.69	8.10	1.59	76.15	355
Sorghum soya blend	7.89	11.92	2.62	12.71	9.77	2.94	63.22	330
Sorghum Rawa	8.97	7.15	1.20	9.23	7.92	1.31	77.74	350
Sorghum Pasta	11.47	8.39	1.38	5.56	4.82	0.74	76.21	355
Sorghum flakes	13.80	5.09	2.40	5.97	5.43	0.54	74.90	342
Sorghum Biscuit	5.67	4.59	24.50	5.27	3.54	1.73	60.29	481

Source: Dayakar et al, 2018. Nutritional and health benefits of nutria-cereals. ICAR-IIMR Hyderabad, India. pp 96.

Parboiling

Parboiling is basically the process of partial cooking of grain along with husk or bran. The raw grain is briefly steamed. The resulted product is dried, de-husked and decorticated.

Milling

Milling is the process of separating bran and germ from the starchy endosperm so that the endosperm can be ground into flour and rawa using different types of sieves in a hammer mill. Milling is to separate the seed coat or decortication reduces protein, dietary fiber, vitamins and mineral contents of the grains to some extent but this is compensated by better consumer acceptability, improved bio-

availability of the nutrients and enhanced product making qualities. The bran fraction from the millets is a very good source of dietary fiber and edible oil.

The de-oiled millet bran may be used as source of dietary fiber in formulating high-fiber foods as it contains negligible or less of silica compared to de-oiled rice bran. The changes in nutritional parameters upon milling and other processing interventions in sorghum are given in Table below.

Chemical, mineral and vitamin composition of upon milling process of sorghum (per 100g)

Parameters	Whole grain	Flour	Fine Semolina (*idli rawa*)	Medium Semolina (*Upma* semolina)
Moisture	11.90	13.80	10.17	8.97
Ash (%)	1.60	1.60	0.73	2.03
Protein	10.40	6.20	6.65	7.15
Fat (%)	1.90	2.80	1.70	1.20
Carbohydrates (%)	72.60	76.15	77.75	77.74
Iron (mg)	4.10	8.40	10.57	5.10
Calcium (mg)	25.00	10.03	7.55	5.75
Chromium (mg)	0.008	0.008	1.27	1.48
Zinc (mg)	1.60	1.30	1.21	1.38
Riboflavin (mg)	0.13	0.38	0.11	1.09
Energy (Kcal/100g)	349	355	350	350

Source: Dayakar et al, 2018. Nutritional and health benefits of nutria-cereals. ICAR-IIMR Hyderabad, India. Pp 96.

Biological value and digestibility of processed millets are given in Table below.

Macro and micro nutrient changes during sorghum processing (per 100g)

Parameters	Medium rawa	Flakes	Vermicelli	Pasta	Pops	Biscuits
Moisture	8.97	13.80	8.43	11.47	5.87	5.67
Ash (%)	2.03	0.63	0.77	0.77	0.63	2.00
Protein	7.15	5.09	8.39	8.39	5.04	4.59
Fat (%)	1.20	2.40	1.38	1.38	2.60	24.50
Carbohydrates (%)	77.74	74.99	76.21	76.21	83.06	60.29
Iron (mg)	5.10	87.78	64.51	64.51	2.40	2.25
Calcium (mg)	5.75	93.15	54.51	64.51	10.26	68.80
Chromium (mg)	1.47	0.90	0.20	0.215	1.40	0.51
Zinc (mg)	1.38	8.78	7.49	5.74	4.51	BDL
Magnesium (mg)	86.02	80.51	67.48	67.48	86.77	56.10
Riboflavin (mg)	01.09	0.02	1.28	1.28	0.15	2.26
Energy (KCal/100g)	350	342	355	355	376	481

Source: Dayakar et al, 2018. Nutritional and health benefits of nutria-cereals. ICAR-IIMR Hyderabad, India, pp 96.

Effect of processing on antioxidant activity of millets

Antioxidants are substances that scavenge free radicals that may cells in our body. Antioxidants are found in many foods, including millets, fruits and vegetables. Antioxidants help to neutralize free radicals in our body, and this is enabled to boost overall health. Different processing methods of foxtail millet made an effect on the total phenolic content (TPC), total flavonoid content (TFC), and the six kinds of phenolic acids. Compared with whole millet, the TPC of dehulled millet decreased and

TFC of dehulled millet increased. Compared with dehulled millet, the TPC and TFC of cooked and steamed millet decreased. However, the total phenolic content and cinnamic acid content were rich in cooked millet. In addition, cooked millet demonstrated remarkable radical scavenging capacity, which was associated with its high contents of natural antioxidants found in the samples, such as phenolic compounds, cinnamic acid, and phytic acid. Correlations between the antioxidant activity and cinnamic acid ranged from 0.75 to 0.89, while the antioxidant activity and total phenolic content ranged from 0.83 to 0.91. Therefore, cooked millet was a good choice for human consumption.

15. Secondary processing of millets

Secondary processing is a process converting primary processed raw material into product which is suitable for food uses or consumption such as ready-to-eat (RTE) and ready-to-cook (RTC) products, minimize cooking time and make it convenient foods. The traditional (popping and flaking) as well as contemporary methods (roller-drying and extrusion-cooking) of cereal processing could be successfully applied to millets to prepare ready-to-eat products, thereby, increasing its utilization as a food.

The pop making technology significantly reduces crude fat and crude fiber contents than raw millet, while the carbohydrate and energy values increase significantly. This is mainly because, fat and fiber contents are higher in outer coat of grains, thus more affected by processing compared with nutrients located in inner layer. Therefore, the use of new technology optimization of puffing conditions, popping technique can be used as a strategy or in combination with other pre-treatments to produce ready-to-eat (RTE) expands from millet grains on a commercial scale, thus promoting utilization of millet grains.

However, because of the rigid endosperm texture, nearly spherical shape and smaller size, heavy duty roller-flaker is essential for flaking unlike the edge runner used for flaking of rice as mentioned in chapter 14. The hydrothermal treatments exploit the thermo-physical properties of starch and prepare flakes. During this process the Maillard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives pleasant and highly desired aroma to the puffed product. It also reduces anti-nutrients like phytates, tannins, etc., increase bio-availability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility.

In addition to these, baking technologies are also developed for the value-added products. Several studies recommended, millets as the nutritional composition, biological and sensory characteristic values are found to be on par with wheat-based products. This has come as a morale-booster and has boost-up the demand for millet-based food products.

Different value-added food products of millets

Instantly ready-to-eat (RTE) products can be prepared reducing the cumbersome time for fermentation. It is gluten free, low calorie, rich source of phenolic compounds, causes satiety resulting in slower digestibility and reduces oxidative stress.

1. Malt from finger millet
2. Millets puffs
3. Extruded snacks
4. Extruded flakes
5. Instant sorghum idli mix
6. Instant upma mix
7. Instant dosa mix
8. Instant pongal mix
9. Millet instant laddu mix
10. Sorghum muesli
11. Millet semolina and pasta
12. Millets vermicelli
13. Millet cookies
14. Millet bread/bun
15. Millet cake
16. Millet pizza

1. Preparation of finger millet (*ragi*) malt

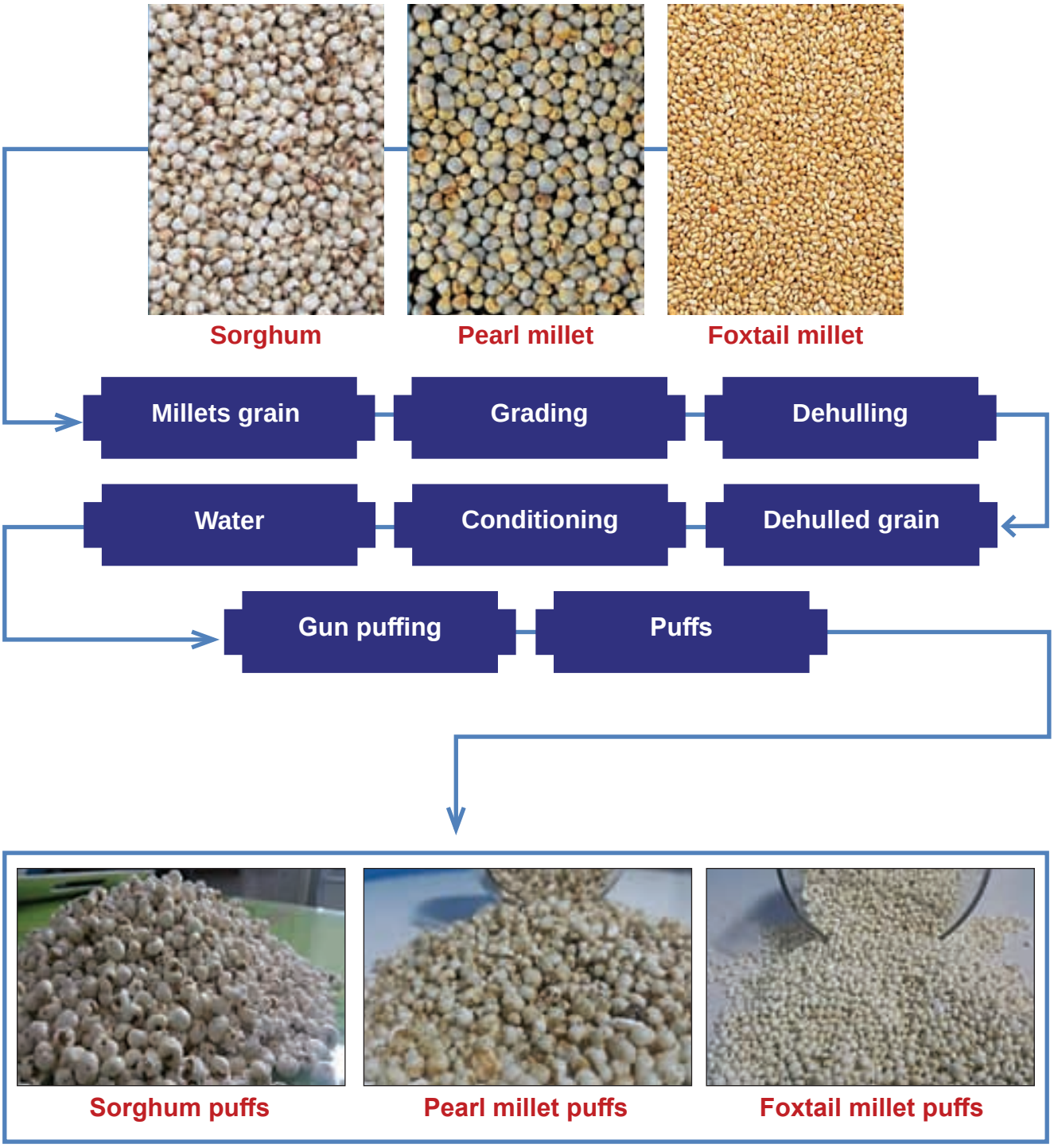
Well cleaned good quality *ragi* having good germination should be used for the preparation of malt. The grain should be first washed in water then steep (soak the grains) in clean soft water in a vessel of appropriate size for a period of 18-24 hrs. Change the water twice or thrice. After soaking for the required period, the grains are taken out and again washed. After draining the excess water, the grains are spread over a gunny bag or thick cloth, spread thinly and allowed for germination for 36-48 hrs depending upon the temperature and humidity. It is desirable to cover the grain kept for germination with another cloth so as it facilitates uniform germination. During germination, water should be sprinkled as and when necessary to keep the sprouts moist. Two days of germination period is sufficient for *ragi*, if germination is allowed too long, root and shoot will grow very long causing high malting loss. During germination set of enzymes that promote digestion of food develops. Important among them are starch, protein and fat digesting enzymes. In finger millet, starch content is more and amylase is the most important enzyme produced.

After, required period of germination the grains are dried in sunlight by spreading thinly on a cloth. Total 6-8 hrs of sun drying should be sufficient. Soon after drying, the rootlets are removed by rubbing grains gently against dry, clean cloth. The separated rootlets are aspirated leaving malted *ragi*.

Malted *ragi* should be mildly toasted or kilned at 65 - 70°C in an iron pan heated at low flame. Malting enhances carbohydrate and protein digestibility and in addition, the water-soluble vitamins is also enhanced along with increase in the bio-available minerals and other nutrients. The roasted grain is grinded into fine flour and sieved through 80 to 100 size mesh or through a muslin cloth. The malt obtained has improved nutritional quality, enhanced digestive enzymes and is an ideal base to prepare weaning foods, infant foods, malted milk foods, health foods, medical foods, etc. The Central Food and Technological Research Institute (CFTRI), Mysore has developed *ragi* malt based weaning food formulation.

2. Puffs from millets

Millet puffs are product which is a resultant of explosive puffing or gun puffing where the millets (sorghum, pearl millet, foxtail millet) grain is expanded to maximum expansion consistent with the grain identity (similar shape of the grain). It is the RTE (ready-to-eat) snack which is developed using puff gun machine. The puff gun machine is loaded with dehulled millets grain onto a rotating barrel and the mixture is roasted for and fired resulting in a puffed millets product. Puffs yield is 94%; by-product yield is 6% (small puffs and un-puffed grains) which varies according to millets.

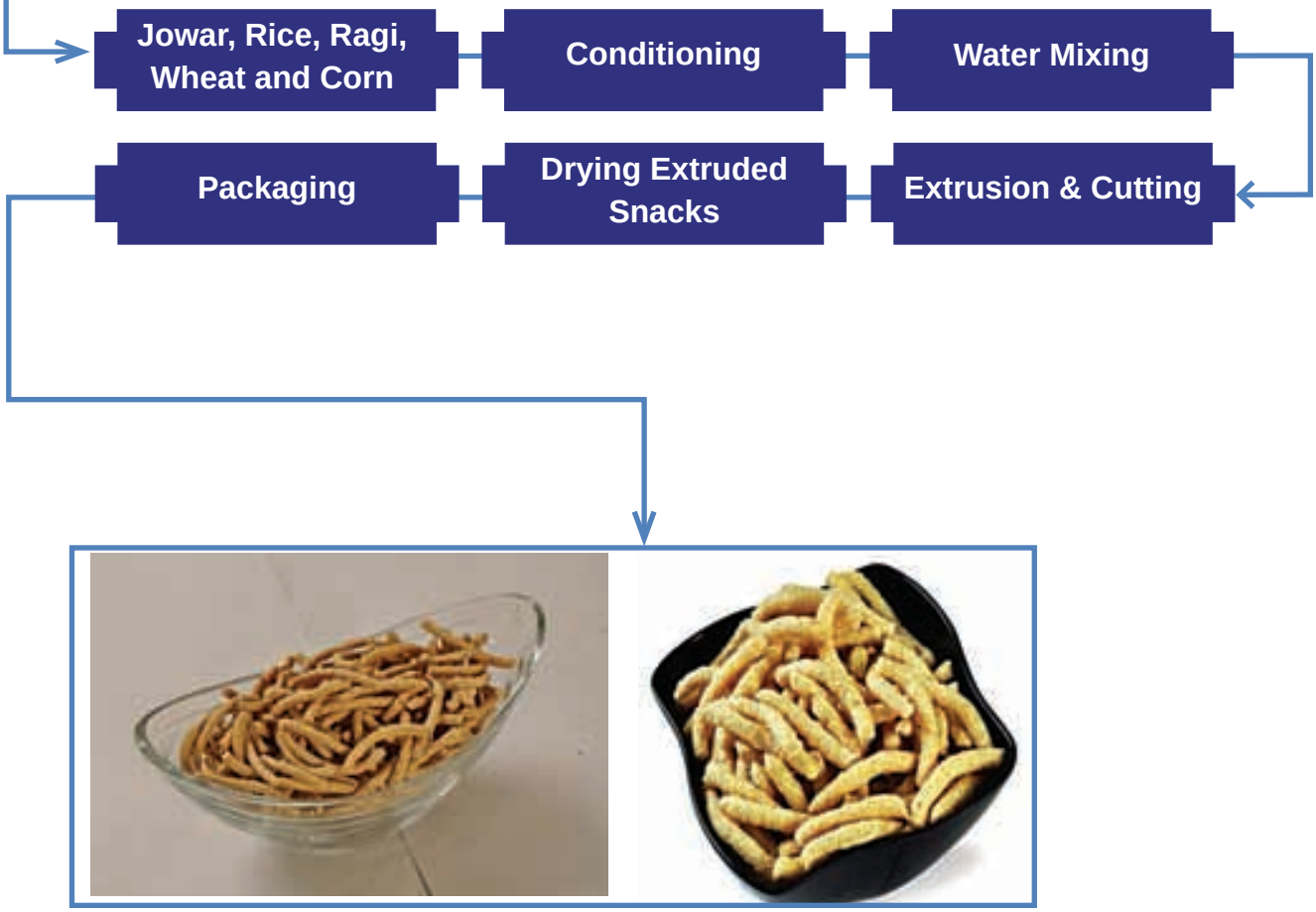


Process of millets puff preparation

3. Extruded snacks

Extruded snacks are ready-to-eat products prepared using twin-screw hot extruder which combines heating with the act of extrusion to create a shaped cooked product through a round, minus shaped dies. Commercially, most of the extruded snacks are prepared from corn; here the extruded snack is made from sorghum grits, rice, ragi, wheat and corn flour. The mixture is combined and passed through twin screw extruder to produce expanded snacks which are ready to eat. The snack can be coated with desired spices to create variations in the taste and flavor. Snacks yield is 90% and by-product yield is 10% obtained (Extrudate by-product) which varies according to millets.

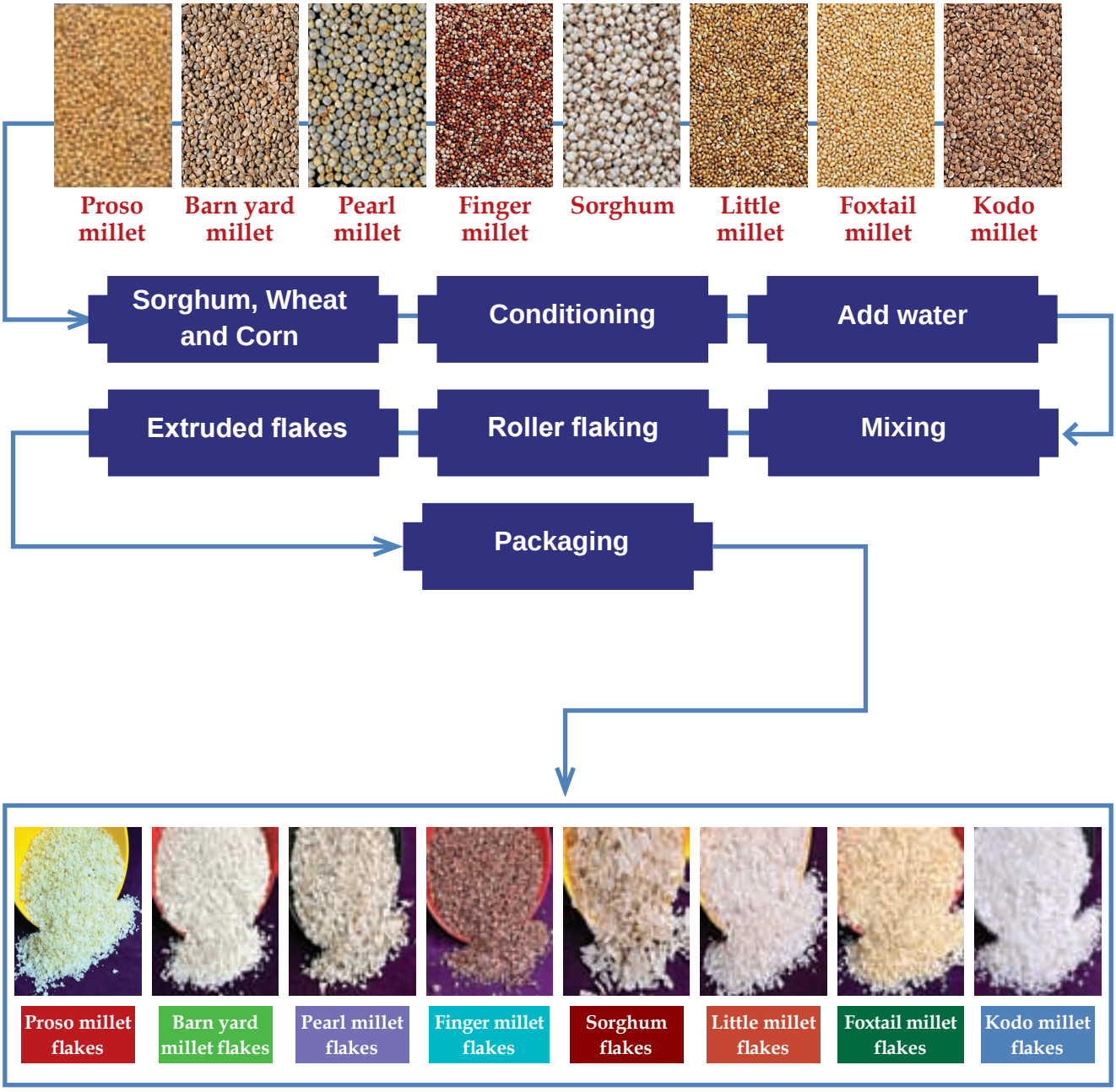
Millet grains



Process of ready-to-eat (extruded snacks) preparation

4. Extruded flakes

Extruded flakes are ready-to-eat products prepared using twin-screw hot extruder which combines heating with the act of extrusion to create round-shaped product which is further flattened in roller flaker machine. The extruded flakes is made from sorghum grits, wheat and corn flour. The snack can be coated with desired spices to create variations in the taste and flavor. Flakes yield is 88% and by-product yield is 12% obtained (Extruded by-product, un-flattened flakes) which varies according to millets.

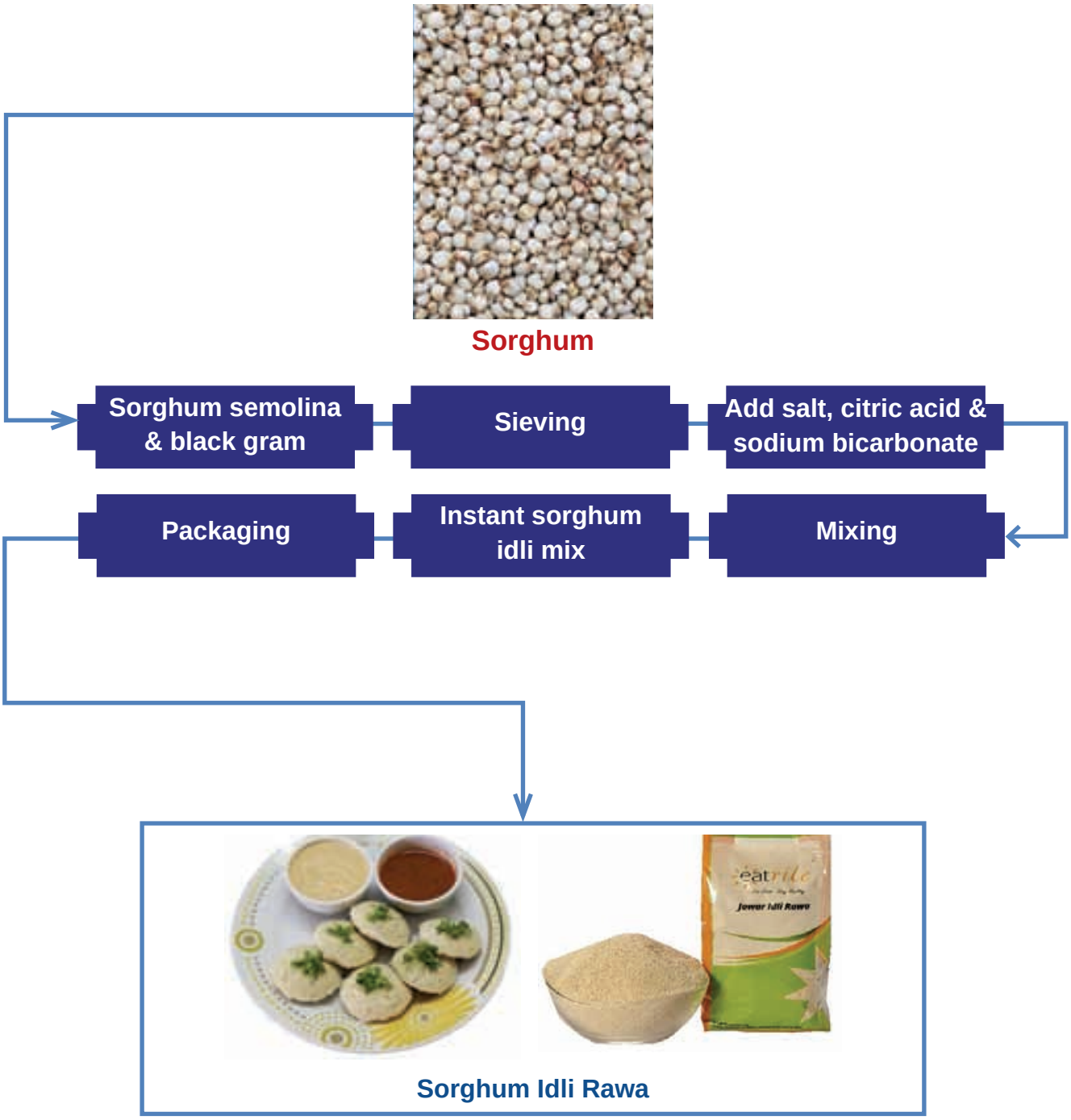


Process of extruded flakes preparation

Instant mixes

5. Instant sorghum *idli* mix

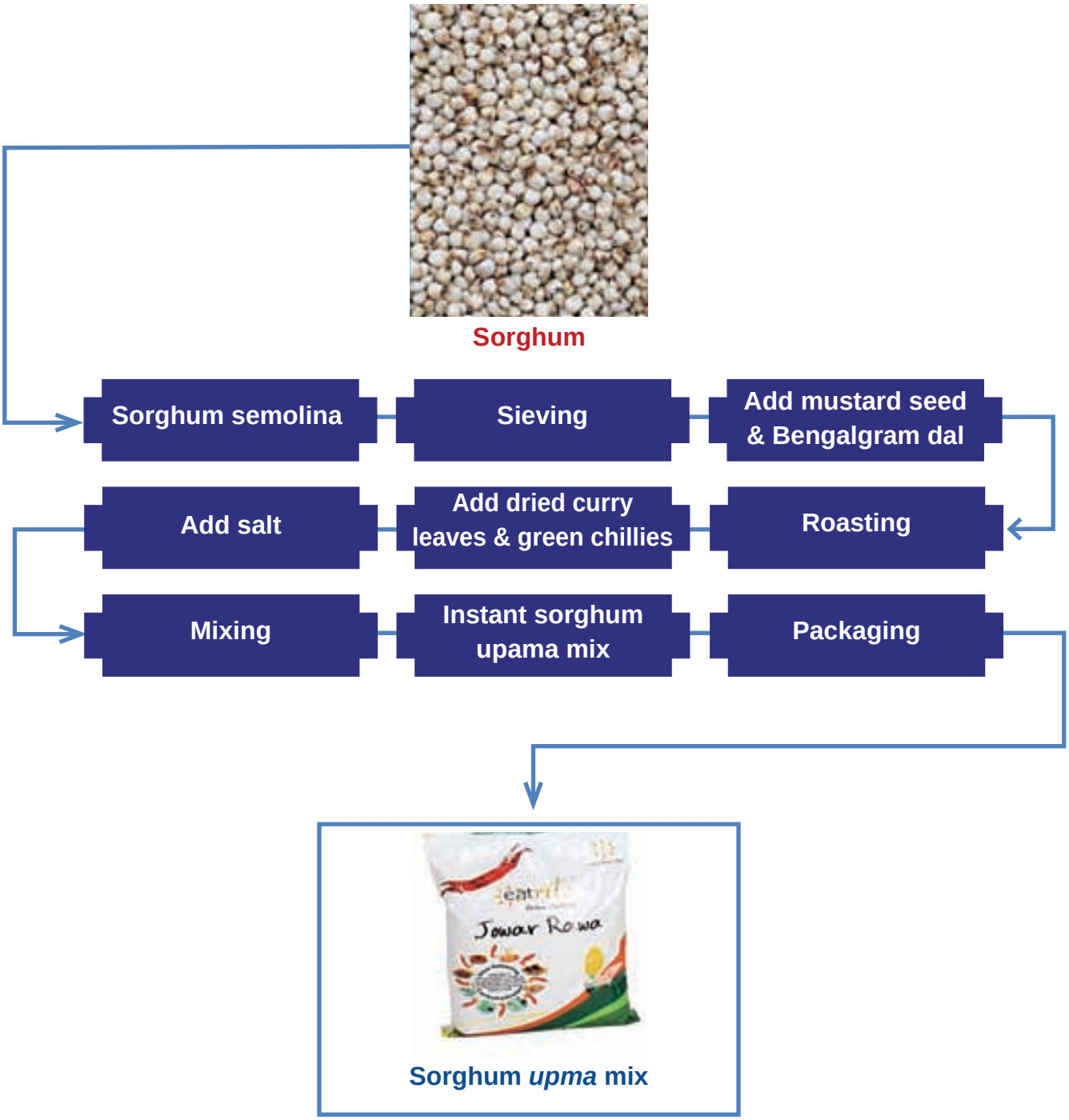
Idli is an indigenous traditional breakfast food in mostly southern Indian cuisine, which is a steamed product made from rice semolina and ground pulses and typically served with a spiced-vegetable filling or chutney. We have made an attempt to prepare instant sorghum *idli* mix sorghum fine semolina, blackgram *dhal*, salt and food grade additives; citric acid and sodium bicarbonate were used as main ingredients. All the ingredients were mixed uniformly in a blender. The formulated mix was packed in a MPET packing material. The shelf life of *idli* mix is 3 months.



Process of instant idli mix preparation

6. Instant *upma* mix

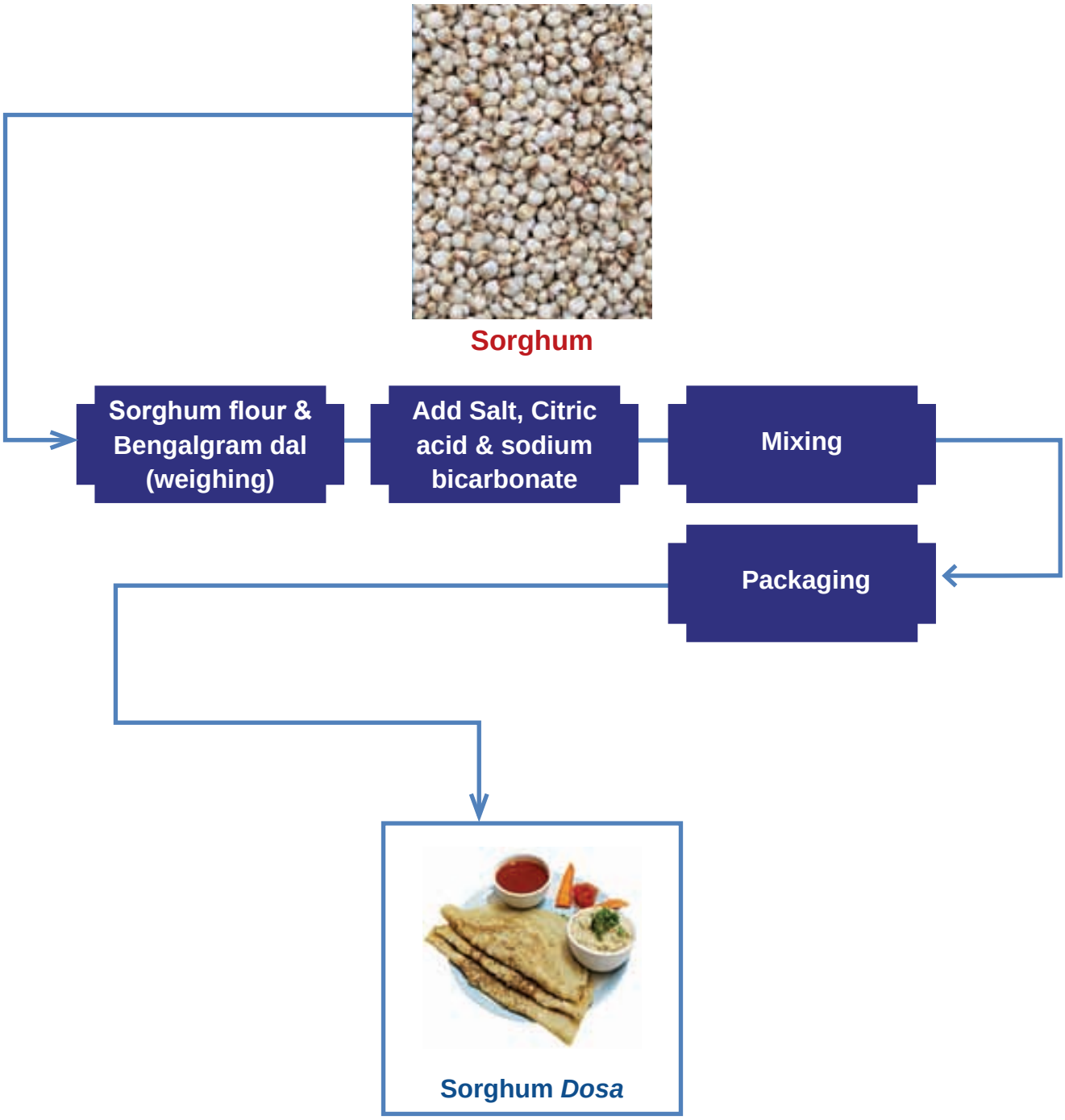
Upma is an indigenous traditional breakfast food in mostly southern Indian cuisine, which is boiled semolina made from wheat/rice with added pulses, condiments and spices. We have made an attempt to prepare instant sorghum *upma* mix sorghum semolina, bengalgram *dhal*; mustard seeds, curry leaves, dried green chillies, salt, and oil were used as ingredients. Semolina, mustard seeds and bengalgram *dal* were roasted separately. To the semolina, roasted mustard seeds, bengalgram *dal*, dehydrated curry leaves, salt and were added and mixed. The formulated mix was packed in a MPET packing material.



Process of instant *upma* mix preparation

7. Instant *dosa* mix

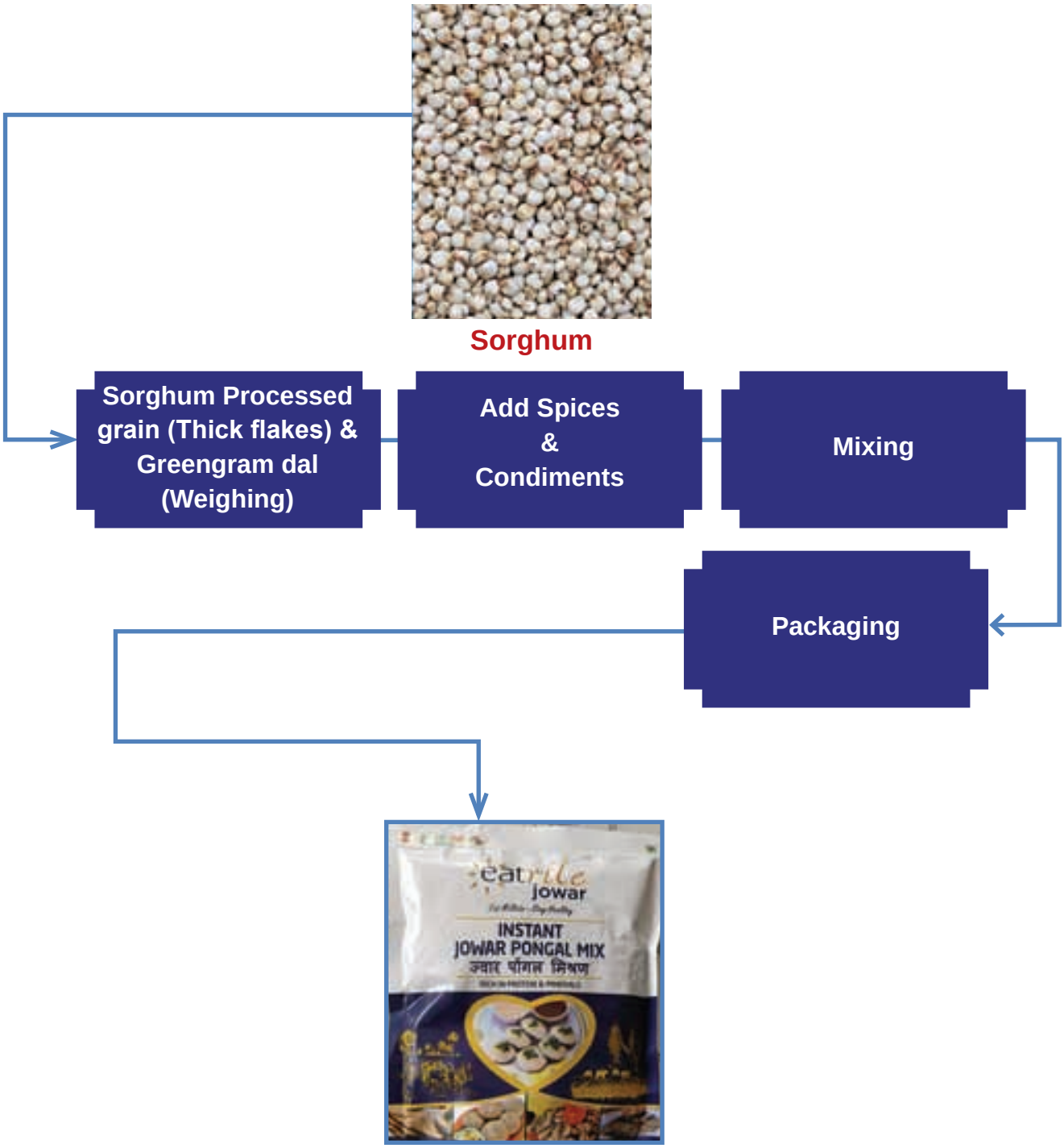
Dosa is an indigenous traditional breakfast food in mostly southern Indian cuisine, which is a pancake made from rice semolina and ground pulses and typically served with a spiced-vegetable filling or chutney. We have made an attempt to prepare instant sorghum *dosa* mix sorghum flour, blackgram *dal* (2:1), salt; citric acid and sodium bicarbonate were used as main ingredients and mixed uniformly in a blender. The formulated mix was packed in a MPET packing material. The shelf life of *dosa* mix is 6 months.



Process of Instant *dosa* mix preparation

8. Instant *pongal* mix

Pongal is a delicious south Indian traditional breakfast recipe, generally prepared from rice and greengram. An attempt was made to prepare instant *pongal* mix using processed sorghum, greengram *dal*, spices and condiments. The mix has to be added to three cups boiling water and cooked in pressure cooker for upto three whistles mixed with ghee or milk to make round balls before serving. The formulated mix was packed in a MPET packing material



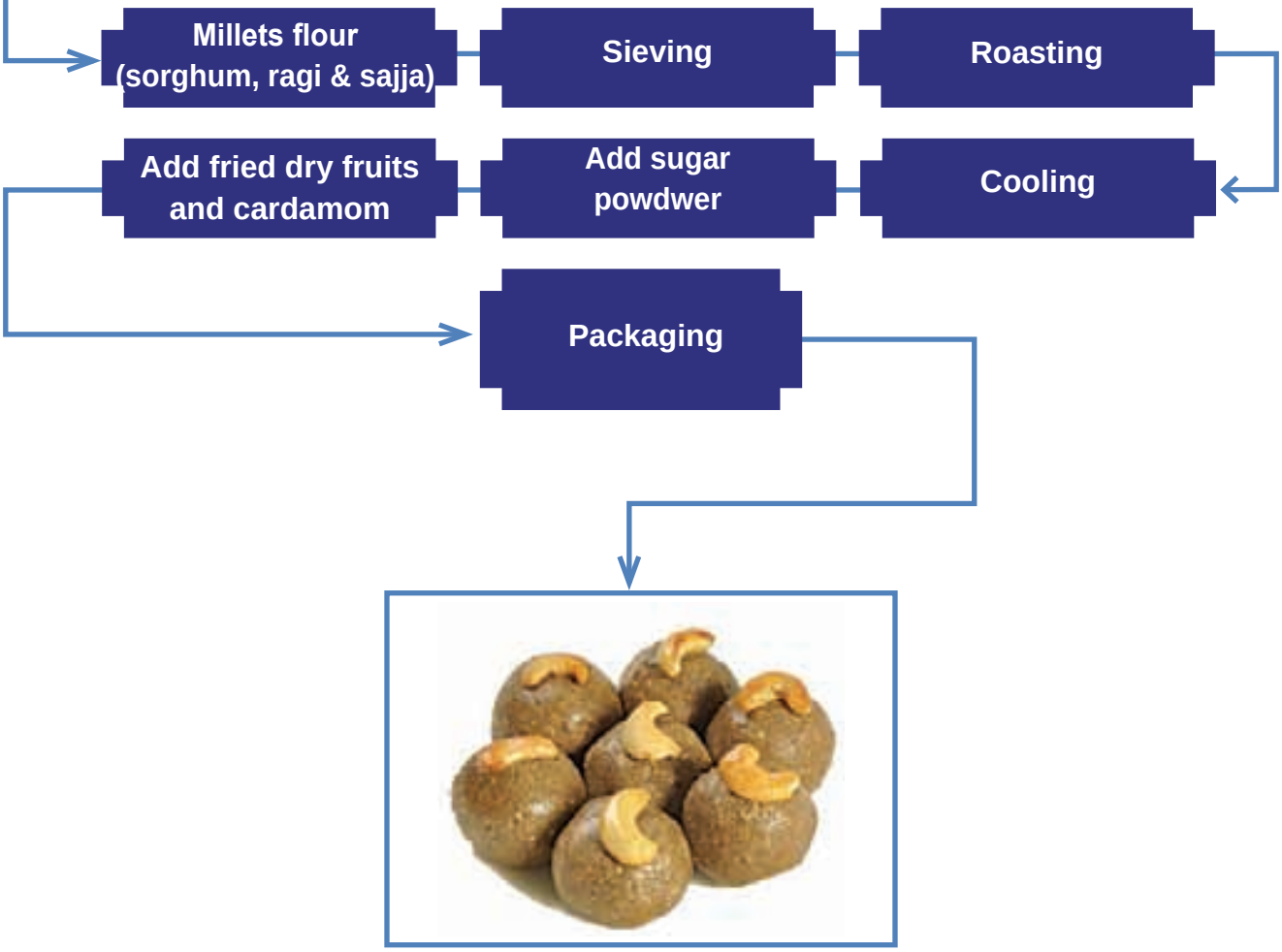
Process of instant pongal mix preparation

9. Millet instant *laddu* mix

Laddu is an Indian sweet made from a mixture of flour/semolina, powdered low calorie sugar, and shortening, which is shaped into a ball. It is developed from roasted sorghum fine *rawa*, finger millet flour, pearl millet flour; adding to it powdered low calorie sugar, dry fruits and cardamom are added. The mix has to be mixed with ghee or milk to make round balls before serving. The formulated mixture was packed in a MPET packing material

Sorghum

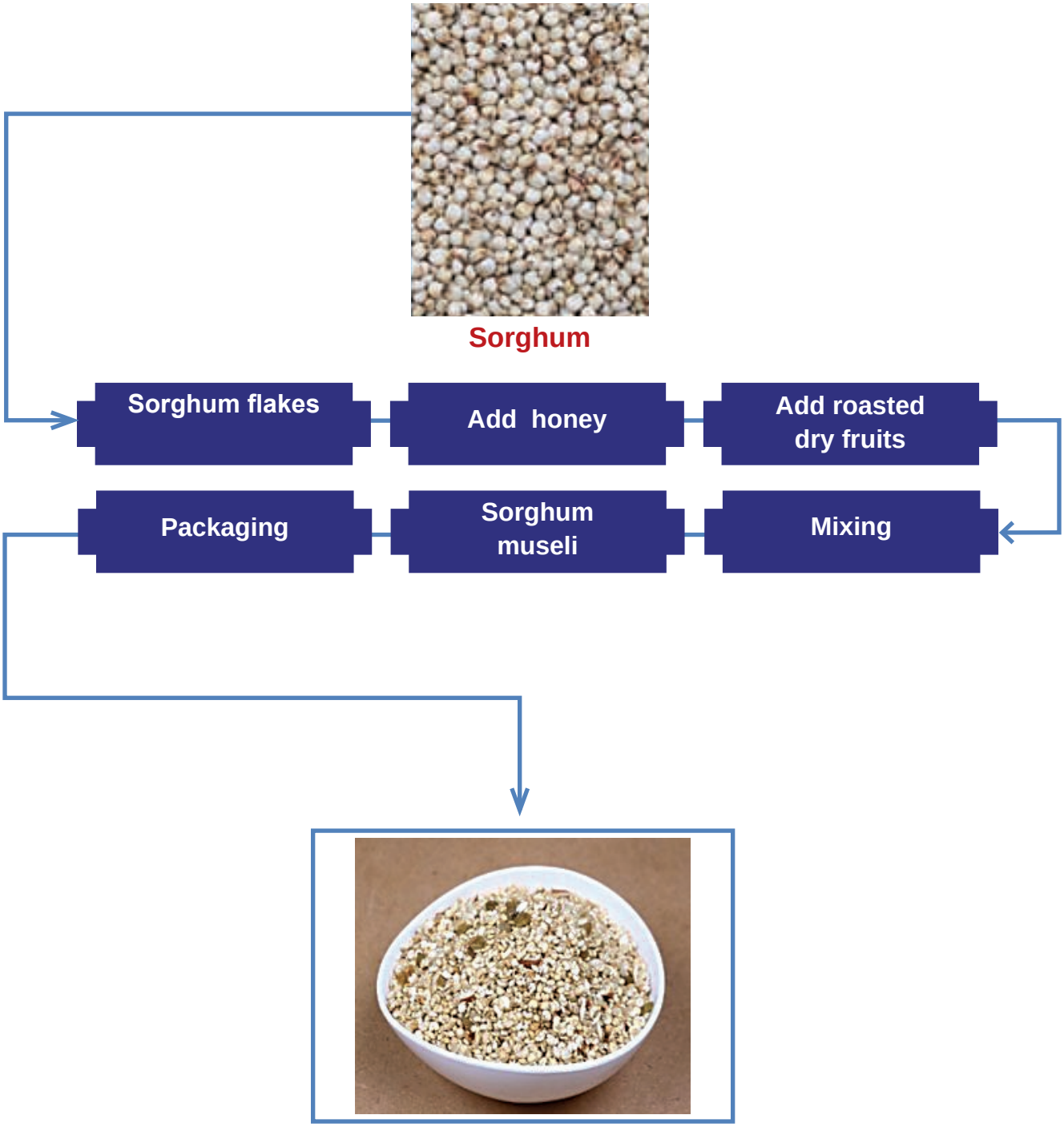
Finger Millet



Process of instant laddu mix preparation

10. Sorghum *muesli*

Muesli is a product made by mixing of honey and dry fruits to sorghum flakes. An attempt was made to prepare sorghum muesli mix where, thick flakes were dry roasted and then coated with honey. Cashew nuts, almonds, pista, raisins were roasted and added to this. The shelf life is for period of one year.



Process of sorghum muesli preparation

11. Millets semolina (*Rawa/Suji*)

Semolina are ready to cook foods. Millet grains (Pearl millet, Finger millet and Foxtail millet) are processed by dry milling. The dry milling process starts with the cleaning of grains. The cleaned grain is milled by the hammer mills to separate the endosperm, germ and bran from each other to get semolina. Millets semolina has three variants. Millet grain is pulverised to get semolina; variants differ with particle size. According to the variant, need to use mesh size in the mill is adjusted. Coarse semolina (*Kichidi raw*a) yield is 68-72% and by-product yield 32-28% (contains medium/fine semolina, flour and bran). Medium semolina (*Upma rawa*) yield is 71-76% and by-product yield is 29-24% (contains coarse/fine semolina, flour and bran). Fine Semolina (*Idli rawa*) yield is 74-80% and by-product yield is 26-20% (contains coarse/medium semolina, flour and bran). The output varies according to millets.

Sorghum grains

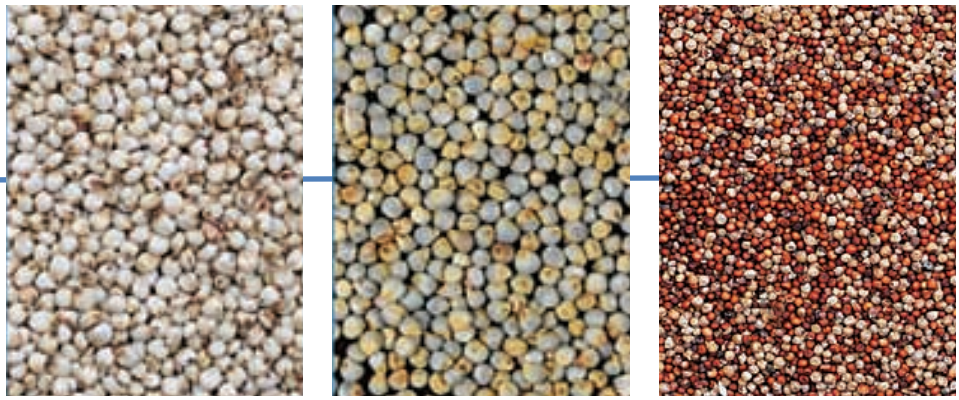
Pearl millet

Finger millet

Process of millets rawa/suji preparation

12. Millets vermicelli and pasta

Vermicelli and pasta are prepared using cold extrusion. This is very useful because of its low cost and continuous processing capability has been accepted as one of the most useful technologies during the recent years in the field of food processing. Finger millet /Foxtail millet /Pearl millet semolina and refined wheat semolina are blended in the mixing compartment of the vermicelli-making machine and blended with water for 30 minutes and extruded using a round die. The vermicelli is allowed to temper in room temperature for 8 hours and then dry in a cabinet drier for 6 hours. Vermicelli yield is 99% and by-product yield is 1% (negligible) which varies according to millets.



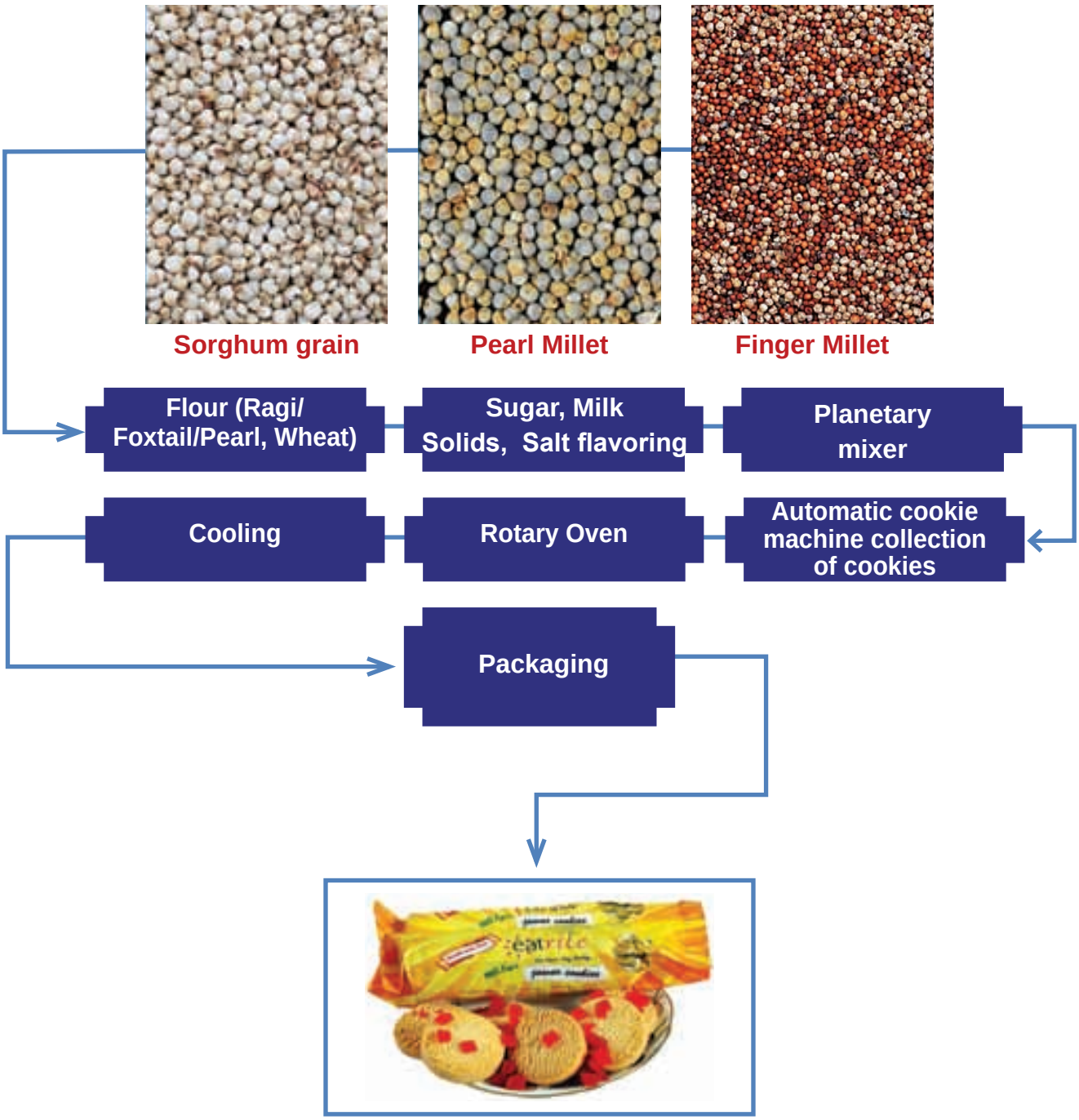
Pearl millet | Foxtail millet | Finger millet

Process of millets vermicelli/pasta preparation

Bakery products of millets

13. Millets cookies

Cookies are popular ready-to-eat product consumed by different age groups in a family. Cookie of 100% millets is prepared using a planetary mixer, automatic cookie making machine and rotary oven. Cookies have been prepared at ICAR-IIMR, Hyderabad using the formulation pearl millet, finger millet and foxtail millet flour of superior quality with addition of sugar, milk solids, trans free-fat, salt and nature identical flavoring substances. Cookie is 92% and by-product yield is 8% (dough left in the machine, Broken cookies or unbaked) obtained in the process.

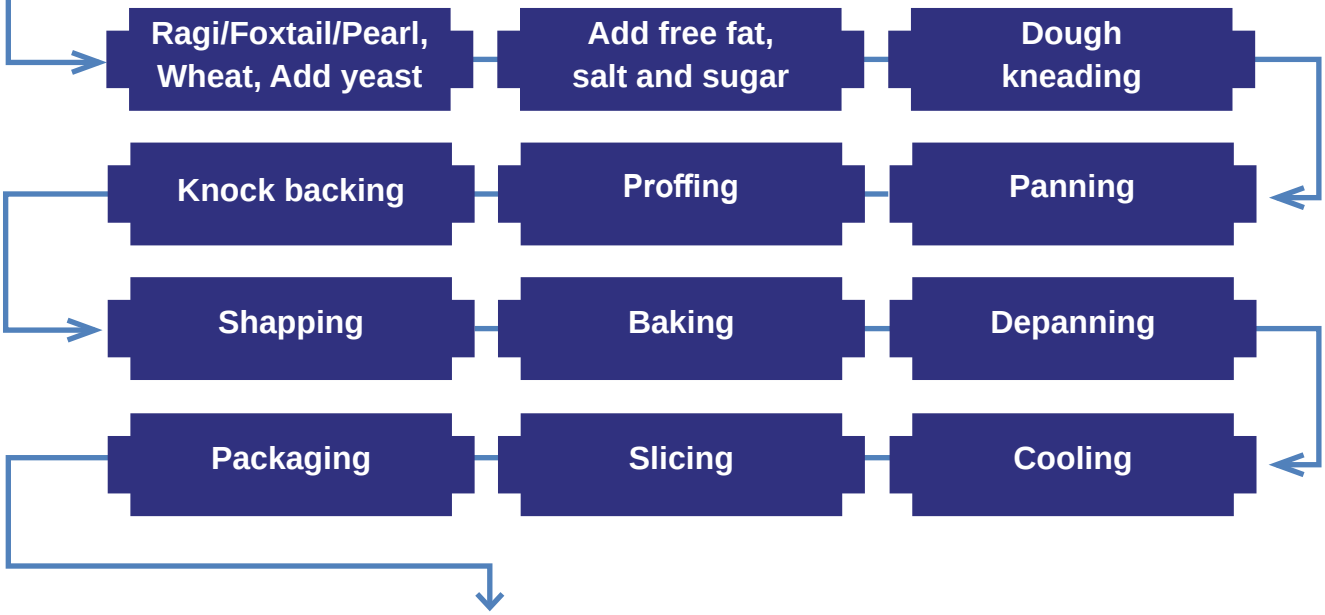


Process of bakery product preparation

14. Millets bread

Bread is an RTE product which is prepared by mixing a mixture of flour, water, fat, salt and yeast until the mixture gets converted into dough, which is followed by baking the dough into a loaf. Millet breads have been prepared at ICAR-IIMR, Hyderabad of replacing 50% wheat in bread with pearl millet, finger millet or foxtail millet flour of varied proportions and adding superior quality yeast, trans-free fat, salt and sugar. The dough is proofed and then, baked in oven to get bread. Round balls of the dough is made and baked to get bun.

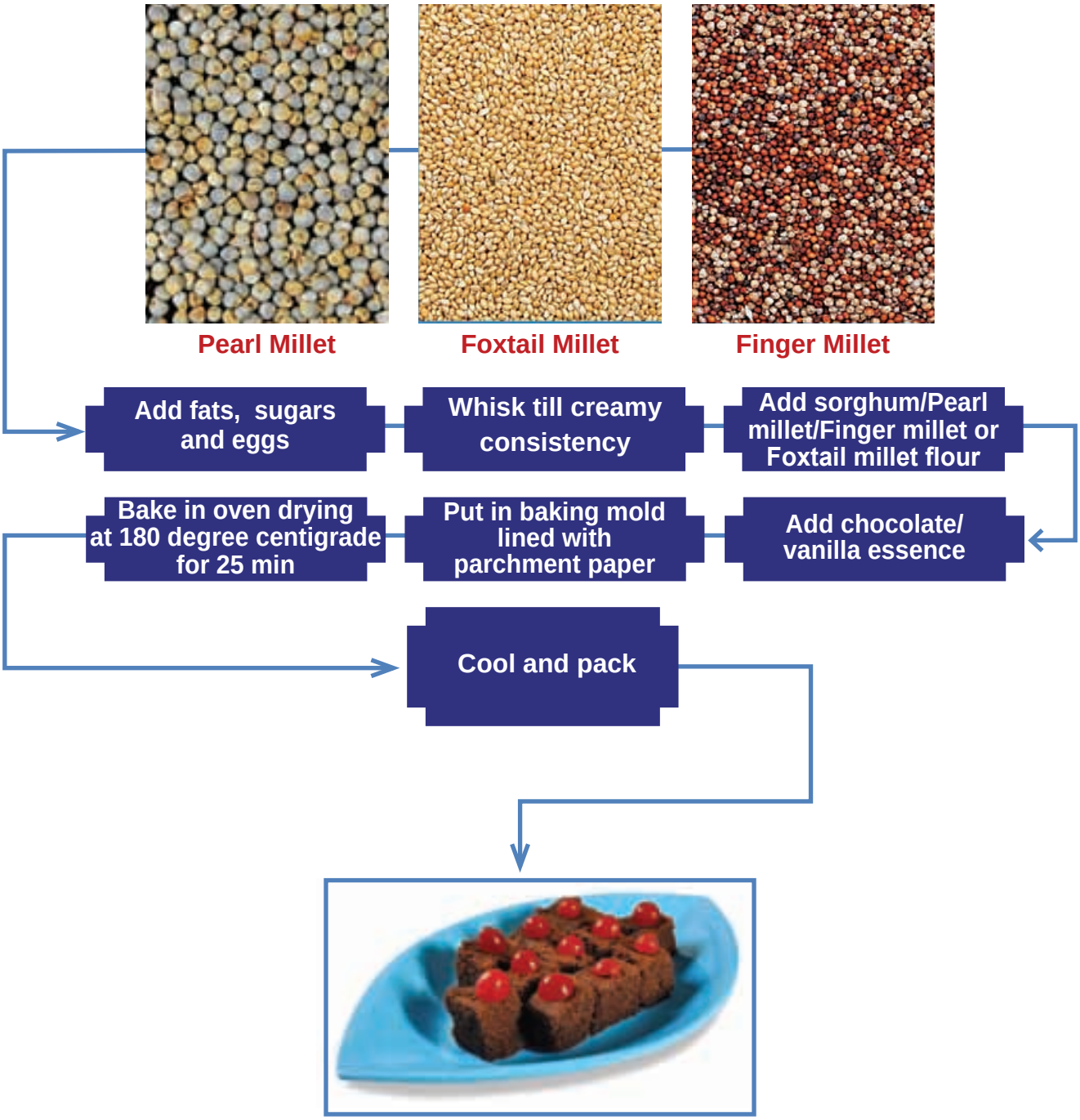
Pearl millet | Foxtail millet | Finger millet



Process of millets bread/bun preparation

15. Millets cake

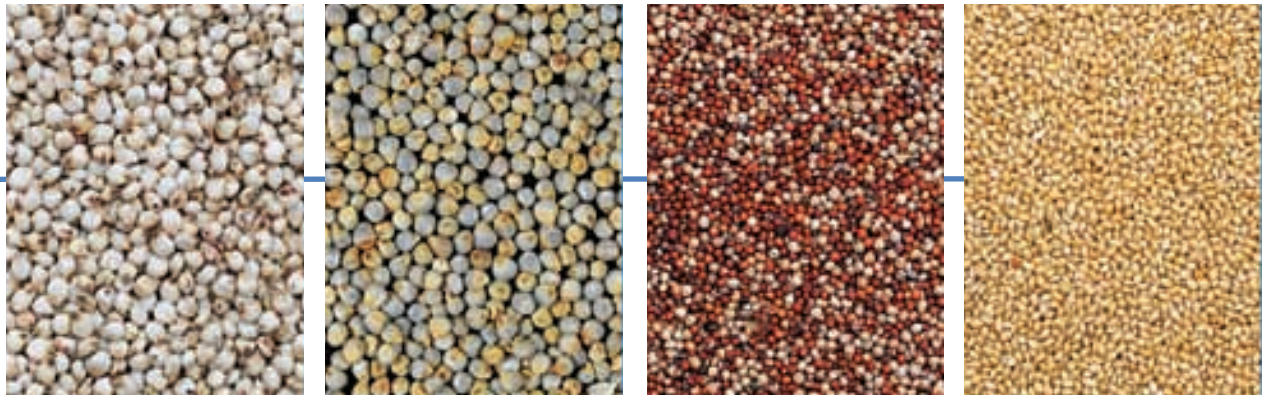
Cake is an RTE product which is prepared by mixing a mixture of flour, sugar, fat, eggs and flavoring ingredients until the mixture gets converted into dough, which is followed by baking the dough. Millet cakes have been prepared at ICAR-IIMR, Hyderabad using 100% pearl millet, finger millet or foxtail millet flour and adding superior quality fat, sugar, eggs and chocolate/vanilla essence; and also adding all the millets together with required proportions. Of all the cakes made out of finger millet cake was highly acceptable.



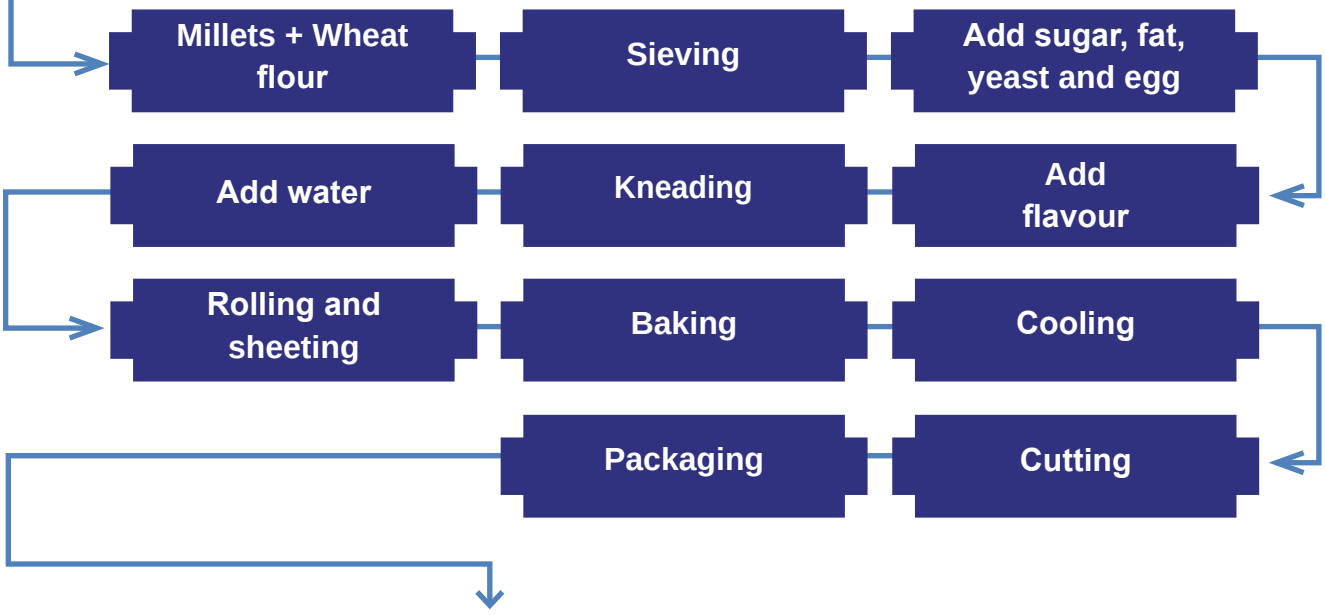
Process of millets cake preparation

16. Millets pizza

Pizza is a ready to eat product which is prepared by mixing a mixture of flour, yeast, salt fat and flavoring ingredients (parsley) until the mixture gets converted into dough, which is followed by baking the dough. Millet pizza have been prepared at ICAR-IIMR, Hyderabad using 50% sorghum, pearl millet, finger millet or foxtail millet flour, 50% fine wheat flour, adding superior quality fat, yeast, salt and sugar; and also adding all the millets together with varied proportions. Of all the pizza base made from sorghum pizza-base was highly acceptable.



Sorghum | Pearl millet | Finger millet | Foxtail millet



Process of millets pizza base preparation

Other novel recipes and traditional products

Pure sorghum indigenous traditional foods are fiber rich beneficial for all age groups. Easy to prepare, have high organoleptic acceptability, rich in magnesium, zinc, iron, dietary fiber and protein, utility as breakfast food and evening snacks.

Sorghum *Bhakarwadi*, Sorghum *Boondi Laddu*, Sorghum *Samosa*, Sorghum Parboiled *Wada*, Sorghum Pancake and Sorghum based *Sharbat* were developed.

Sorghum Bhakarwadi

Sorghum Boondi Laddu

Sorghum Pancake

Sorghum Based Sharbat

Sorghum Parboiled Wada

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