Improved Millet production technologies and their impact

1. Rainy (*Kharif)* sorghum production technologies and their impact
2. Post Rainy (*rabi*) sorghum production technologies and their impact
3. Sorghum production technologies for rice fallows under zero-tillage
4. Forage Sorghum production technologies and their impact
5. Pearl millet (bajra) production technologies and their impact
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10. Barnyard millet production technologies and their impact
11. Value – added millets food products

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IMPROVED MILLETS PRODUCTION TECHNOLOGIES AND THEIR IMPACT

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Little millet

Proso millet

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Abstract

This bulletin is a compilation of research-based recommendations and cultivation practices developed by ICAR-IIMR and ICAR-AICRP-SM on 11 different types of millets including sorghum suitable for different agro-climatic situations. The field performance of last 4-5 years of the improved millet production technologies is also reflected as testimony for the users. It will serve as reference of improved millets production technologies to the researchers, academicians, extension functionaries and policymakers.

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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

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MESSAGE

Millets are important cereal crops which have to play a significant role in national food and nutritional security. They have potential to support in feeding the mouths of increasing population due to its unique trait that sustain production and productivity in adverse climatic conditions, where other fine cereals can't do well. Despite the fact, their area under cultivation is going down. With changing needs of the people and time, these are facing strong competition from commercial and vegetable crops. However, the average sorghum productivity has increased from 522 kg/ha in 1969 to 780 kg/ha in 2015-16. More could be achieved by adoption of improved production technologies by the farmers. Millets are now-a-days being utilized for various purposes such as food, feed, fodder and more recently, as bio-fuel. Several potential technology and viable options are available for enhancing grain and fodder production, through intercropping, drought management, rainwater conservation, nutrient management, plant protection, market-oriented products and storage. These needs to be introduced at grassroot level through extension agencies to achieve the goal. For this, knowledge on the improved production technologies has vital role to create awareness among the end users for their adoption. In this regard, it is essential to have compiled information on improved technological advancement of different millet crops which has been generated at various network centres and research organizations located in different millets growing areas of the country.

I am pleased to learn that the ICAR-Indian Institute of Millets Research team has come up with the handy publication "**Improved millets production technologies and their impact**" with viable technologies of millets cultivation. I place on record of my appreciation to all the contributors of the technologies and I am sure it will be useful to the end-users and policy makers alike to promote millets farming. I compliment ICAR-IIMR team of scientists for their concerted efforts in bringing out this useful bulletin.

Dated the 3rd April, 2018
New Delhi

(T. MOHAPATRA)

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- Authors

Vernacular names of millets in different languages

English	Hindi	Marathi	Kannada	Telugu	Tamil	Bengali	Gujrathi	Oriya	Punjabi
Sorghum	Jowari	Jwari	Jola	Jonna	Cholam	Jowar	Jowari	Juara	Jwar
Pearl millet	Bajra	Bajri	Sajje	Sajja	Kambu	Bajra	Bajri	Bajra	Bajra
Finger millet	Ragi, Mandika, Marwah	Nagli, Nachni	Ragi	Ragulu, Chodi	Keppai, Kelvaragu	Marwa	Nagli, Bavto	Mandia	Mandhuka, Mandhal
Foxtail Millet	Kakum	Kang, Rala	Navane	Korra	Thenai	Kaon	Kang	Kanghu, Kangam, Kora	Kangani
Little millet	Kutki, Shavan	Sava, Kutki	Same, Save	Samalu	Samai	Sama	Gajro, Kuri	Suan	Swank
Proso millet	Chena, Barri	Vari	Baragu	Variga	Pani Varagu	Cheena	Cheno	Bachari bagmu	Cheena
Kodo millet	Kodon	Kodra	Harka	Arikelu, Arika	Varagu	Kodo	Kodra	Kodua	Kodra
Barnyard millet	Sanwa, Jhangora	Bhagar	Oodalu	Udhalu, Kodisama	Kuthiraivali	Shyama	-	Khira	Swank

Source: http://www.aicrpsm.res.in and personal communication with trial farmers

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1 Introduction

A significant increase in food grain production in recent times made India a potential exporting country besides maintaining a buffer stock of 60 million tonnes. It was achieved through green revaluation. The major driving forces in achieving this was; introduction of high yielding production technologies like, high yielding variety (HYV) seeds, chemical fertilizers and intensive irrigation, improved pest and disease management, input subsidization and incentives to farmers through remunerative pricing policies for some crops, public investment in agricultural research and education, and institutional reforms. These reform measures have paid back significantly to increase the agricultural production in the country and resulted in 45% increase in per capita food availability.

Dryland/rainfed farming is the practice of cultivating land, which derives water only through rains. Hence, an understanding of rainfall patterns and land characteristics is crucial for optimizing the use of available water for dryland crops. The productivity of dryland crops is still very low because of low and erratic rainfall and poor adoption of improved technologies. To bridge yield gap, the crop diversification is required for increasing the productivity and profitability per unit area. Intercropping is also an efficient strategy that can be followed with suitable options in the present climatic scenario. Apart from rainfall, two other important elements include, moisture availability to crops and availability of suitable production technologies. Priority needs to be given on conservation of soil moisture and crop management practices. The productivity of dryland crops is very low because of low and erratic rainfall and poor adoption of improved technologies. To bridge this gap, the crop diversification is required for increasing the productivity and profitability per unit area and per unit time. Intercropping is also an efficient strategy that can be followed to get desirable outcomes.

Millets are one of the most important dryland crops which are being cultivated in larger parts of this country from ancient times. These crops were cultivated in wide ranges of climatic conditions and marginal conditions of soil and moisture. The dryland/rainfed agriculture is meant by scientific management of soil and crops under dry lands without irrigation. Areas which receive an annual rainfall of 750 mm or less, and there is no irrigation facility for raising crops are categorized as drylands. Millets are the most viable option in the dryland conditions as they require minimum water and can withstand in adverse weather conditions.

Despite the fact that, area under millets cultivation has been drastically reduced over the years in India. It is one among the major producers of millets in the world. This is due to productivity gains in millets which showed some increase despite shrinkage of area. With the increase in population, the per capita availability of food grains including cereals has decreased over the years. Whereas under stress tolerance conditions, millets provides nutritious food as compared to others cereals with high fibre content, minerals and slow digestibility. The millets can constantly help to meet out the needs of their animal feed and fodder, and will continue to be grown by dryland and resource poor farmers in the foreseeable future. The millets are one of the cheapest sources of energy, high content of digestive fibre, protein, vitamins and minerals. In terms of nutrient intake, sorghum accounts for about 35% of the total intake of calories, protein, iron and zinc in the dominant production/consumption areas. Nutritional relevance of sorghum and other major cereals is given in Table 1.

Table 1 Nutritional composition of staple cereals (per 100 g)

Staple cereal	Protein (g)	Carbohy-drades (g)	Fat (g)	Crude fibre (g)	Mineral matter (g)	Calcium (mg)	Phosp-horus (mg)
Sorghum (*Jowar*)	10.4	72.6	1.9	1.6	1.6	25	222
Pearl millet (Bajra)	11.6	67.5	5.0	1.2	2.3	42	296
Finger millet (Ragi)	7.3	72.0	1.3	3.6	2.7	344	283
Foxtail millet	12.3	60.9	4.3	8.0	3.3	31	290
Barley	11.5	696	1.3	3.9	1.2	26	215
Maize	11.5	66.2	3.6	2.7	1.5	20	348
Wheat	11.8	71.2	1.5	1.2	1.5	41	306
Rice	6.8	78.2	0.5	0.2	0.6	10	160

Source: National Institute of Nutrition (NIN), Hyderabad.

Production of cereal demands more water and fertilizers than millets. Millets are hardy crops and can grow under less favorable conditions and have potential to bridge the gap between demand and supply to ensure nutritional security. While, the population pressure continues, the area under arable land is decreasing. In spite of a wider climatic adaptability, cultivation of diverse millet species/varieties is gradually decreasing in the recent past. Lack of institutional support for millet crops in contrast to rice and wheat continue to shrink the millet-growing area. In spite of this, several communities in the dry/rain fed regions

having known the food qualities of millets over generations continue to include a range of millets in the traditional cropping patterns and recognize millet as an essential part of the diet. Unlike in other parts of the world, almost all the millets are grown in rainy season while a few like, sorghum and pearl millet are grown in post-rainy season in India, and used for human consumption, livestock feed, and raw materials for industries. Thus, millets are the key for the sustenance of human and livestock population in an era of perceptible climatic changes.

Introduction of millets cultivation in dry/rainfed farming of the country will help to support the farmers' livelihood in the coming years. For this, knowledge on the improved production technologies has vital role to create awareness among the end users and for wide adoption. In this regard, it is essential to compile information on latest technological advancement of different types of millets which were generated from different network centres and research organizations located in different parts of the country (Fig. 1). An effort has been made to bring latest technical knowledge on millets production technologies with their field performance as a testimony for the users in this bulletin for the different stakeholders. It comprised of research-based recommendations and cultivation practices of 11 different types of millets including sorghum suitable for different agro-climatic situations in the country.

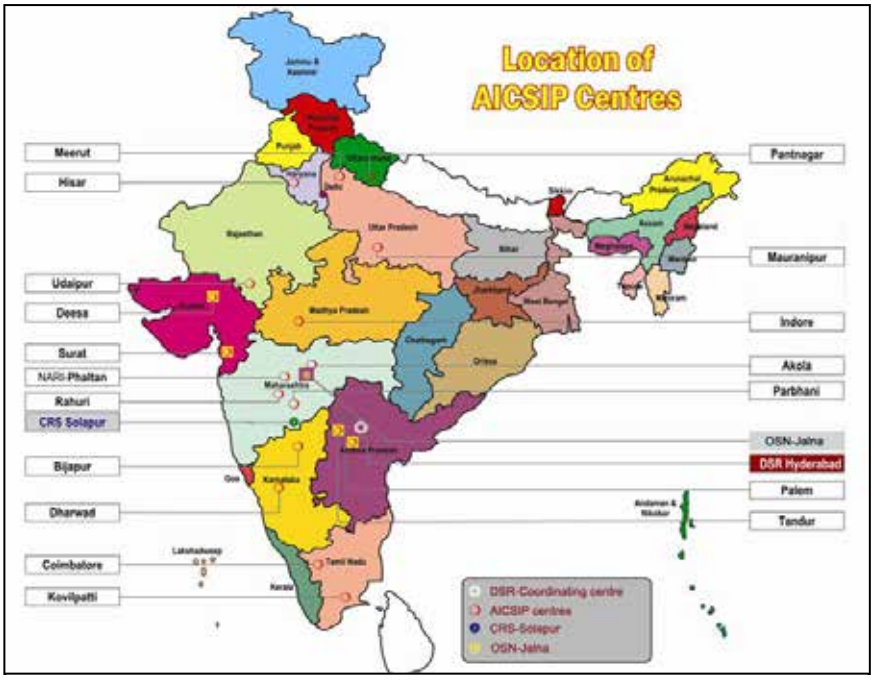


Fig. 1. Location of all India Research Network Centres

2 Rainy (*kharif*) sorghum production technologies and their impact

Sorghum

(*Sorghum bicolor* (L.) Moench)

Common name: Jawar, Great millet

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

Family: Gramineae

Sorghum is an important cereal crop grown for food, feed and fodder in mostly dryland rainfed ecosystems of the country. In India *kharif* sorghum is grown in an area of 28.92 lakhs hectare and *rabi* sorghum 46.39 lakhs ha. Maharashtra (54%), Karnataka (18%), Rajasthan (8%), Madhya Pradesh (6%) and Andhra Pradesh (4%) are the major sorghum growing states. Though, the area under sorghum has declined from 18.61 m. ha in 1969-70 to 5.65 m. ha in 2015-16, its productivity has increased from 554 kg /ha to 780 kg /ha during the same period due to adoption of improved production technologies developed by the research institutes. However, there is wide gap between yield obtained by the farmers and yield potential of the improved sorghum technologies developed from the research institutes due to several reasons.

Origin

Sorghum was originated and domesticated in northeast Africa. These areas represent the diversity and abundance of wild and weedy species as well as primitive race of bicolor. The secondary center of origin of sorghum is the Indian sub-continent. It might have reached India not earlier than 1500 BC and China by 900 AD.

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 conditions. 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 crops. Sorghum requires about 26-30^{o}C temperature for good growth.

Soil

Grain sorghum can be grown on many different soils. Sorghum will yield best on deep, fertile, well-drained loamy soils. However, it is quite tolerant to shallow soil and drought conditions.

Usage

1. To meet out the need of fodder and feed for animals and poultry in dry land rainfed areas
2. Diversion of *kharif* grain over past three decades is increasing from food to industrial purposes such as biofuel, potable alcohol, starch, alternate food products, etc.
3. A major source of nutritious and healthy food to the resource poor population in dryland agricultural areas

High yielding cultivars

Region / state	Production condition	Recommended Hybrid	Recommended Variety
Maharashtra	Medium to heavy soil areas	CSH 16, CSH 18, SPH 388, CSH 23, CSH 25, CSH 30	CSV 15, PVK 400, CSV 17, CSV 20, CSV 23
Karnataka	Low rainfall areas	CSH 14, CSH 17, CSH 30,	CSV 17
	Normal rainfall areas	CSH 16, CSH 13, CSH 18, CSH 23, CSH 30	CSV 15, DSV 2, DSV 3
Andhra Pradesh	Low rainfall areas	CSH 14, PSH 1	CSV 15, CSV 17, CSV 20, CSV 23
	Normal rainfall areas	CSH 23, CSH 25, CSH 30	CSV 15, CSV 20, CSV 23
Madhya Pradesh	Entire state	CSH 16, CSH 17, CSH 18, CSH 23, CSH 25	CSV 15, CSV 17SPV 235, JJ 741, JJ 938,
Gujarat	Normal rainfall areas	CSH 16, CSH 17, CSH 18, CSH 23, CSH 27	CSV 15, GJ 38, GJ 40
	Low rainfall areas (North Gujarat and Saurashtra)	CSH 17, CSH 13, CSH 16, CSH 18	CSV 15, CSV 17, GJ 38, GJ 39, GJ 40, GJ 41
Rajasthan	Medium to heavy soil zone	CSH 14, CSH 23, CSH 25, CSH 27	CSV 15, CSV 17, CSV 20, CSV 23
	Semi-arid & transitional zones	CSH 16, CSH 18, CSH 23	
Tamil Nadu	Coimbatore & Madurai districts	CSH 14, CSH 17	CO 26, CSV 15, CSV 17, CSV 20, CSV 23
	Entire state	CSH 16, CSH 17, CSH 18, CoH 2, CoH 4, CSH 27	
Uttar Pradesh	Entire State	CSH 14, CSH 16, CSH 18, CSH 23, CSH 25, CSH 27	CSV 15, CSV 17, CSV 20, CSV 23
Sweet Sorghum (All India)	All above sorghum growing states	CSH 22 SS	SSV 84, CSV 19 SS
Forage sorghum (All India)	All above sorghum growing states	SSG 59-3, PC 106, CSH 20 MF, CSH 24 MF	HC 308, HC 171, HC 136, HC 260, CSV 15, CSV 20 (SPV 1616)

ii. Improved cultivation practices

Land preparation

- Ploughing once in summer followed by 2-3 harrowings
- Addition of farm yard manure (FYM) 8-10 tonnes per ha
- Soil application of Phorate or Thimate @ 8-10 kg/ha

Sowing time

- 3rd week of June to 1st week of July with on-set of monsoon

Seed rate

- 7-8 kg seeds/ha (3 kg/acre)

Spacing

- Row to row 45 cm and plant to plant 12 to15 cm
- Maintain plant population as 1,80,000 plants/ha (72,000 plants/acre)

Seed treatment

- Treat the seed with 14 ml Imidacloprid + 2 g Carbendazim for one kg of sorghum seed, or Thiomethaxam 3 g/kg of seed

Fertilizers application

- For light soils and low rainfall areas: 30 kg Nitrogen per ha, 30 kg P_2O_5 per ha and 20 kg K_2O per ha at sowing. Apply 30 kg Nitrogen at 30-35 days after sowing (DAS).
- For medium-deep soils and moderate to high rainfall areas: 80 kg Nitrogen per ha, 40 kg P_2O_5 per ha and 40 kg K_2O per ha. Apply half Nitrogen + full P_2O_5 and full K_2O at sowing and remaining Nitrogen at 30 DAS.

Weed control and inter cultivation

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

Intercropping

- Sorghum intercropped with pigeonpea, green gram, soybean and sunflower are beneficial.

- Sorghum and pigeonpea are to be sown in the 2:1 row ratio without additional fertilizers.
- Medium to short duration sorghum genotype like, CSH 16, CSH 17 and CSH 18 are suitable.
- In intercropping, spraying of weedicide/herbicide is not recommended.
- Sorghum and fodder cowpea in 2:2 row provides green fodder, helps to improve soil fertility and check weed growth.

Sequence cropping

- After *kharif* sorghum, a sequence crop in *rabi* like chickpea, safflower and mustard are found most suitable in most of the situations.
- These sequence cropping are found more profitable in areas which receive rainfall above 700 mm and having moisture retentive medium to deep black soils.
- *Kharif* sorghum should be harvested at its physiological maturity to gain about one week time in planting the next crop.

Shoot fly eggs

Shoot fly larvae

Adult

Major insect pests and their management

1. Shoot fly

- Infestation occurs during seedling stage up to 1 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 "deadheart" symptom.

Management

- Early Sowing within 7 to 10 days of the onset of monsoon.
- High seed rate @ 10 to 12 kg/ha is recommended while normal seed rate is 7–8 kg/ha
- Inter cropping of sorghum + red gram in 2:2 ratio.
- Seed treatment with Imidacloprid @14 ml/kg of seed or Thiamethoxam 70 WS @ 3gm/kg of seed may also be used.
- Soil application of Carbofuran 3G granules@20kg/ha in furrows at the time of sowing

Dead heart symptom

2. Stem borer

- It attacks the crop from 2 weeks after germination until crop harvest.
- Irregular-shaped holes on the leaves, caused by the early instar larvae feeding in the whorl.
- Drying of central shoot giving "deadheart" look.
- Extensive stem tunneling.
- After panicle emergence, peduncle tunneling results in their breaking or result in complete or partial chaffy panicles.

Leaf damage

Management

- Uprooting and burning of stubbles and chopping of stems of earlier crop to prevent its carryover.
- Need-based application of Carbofuran 3G , @ 8-12 kg/ ha at 20 and 35 days after emergence inside the whorls of leaf injured plants.
- Intercropping of sorghum with cowpea.

Deadheart

Stem tunnels

Adult

Major diseases and their management

1. Grain mold

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

Grain mould infested panicle

Management

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

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 exert panicles. Even, if panicles are exerted they are small, and have little or no seed set.

Downy mildew infested plant

Management

- Deep summer ploughing to reduce soil-borne oospores.
- Seed dressing with Metalaxyl or Ridomil 25WP @ 1g a.i./kg., followed by foliar spray with Ridomil-MZ @ 3g/liter water.

Harvesting and threshing

Crop should be harvested at physiology maturity (110-120 days after sowing) depending upon the genotypes duration. The harvested panicles are left in the field for about a week for drying and thereafter the grains are separated from panicles by threshing or manually. The panicles are harvested first and remaining plants latter.

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.

Impact of the technologies

- The area under sorghum reduced drastically from 17.37 m ha in 1970-71 to 5.65 m ha in 2015-16. However, due to concerted efforts made by the scientists, extension workers, developmental; agencies and farmers, average productivity has now reached to around 780 kg/ha during 2015-16.

- Improved sorghum cultivars (CSH 23, CSV 20, CSV 23, CSV 17 and CSV 15) demonstrated under frontline demonstrations (FLDs) gave higher grain yield up to 67% and stover yield up to 64% more than the local cultivars during *kharif* 2009 (Fig. 2). On an average, the demonstrated cultivars could give net profits of Rs.17,955/- ha, which was 56% more than the local cultivars (Rs. 11,494/- per ha).

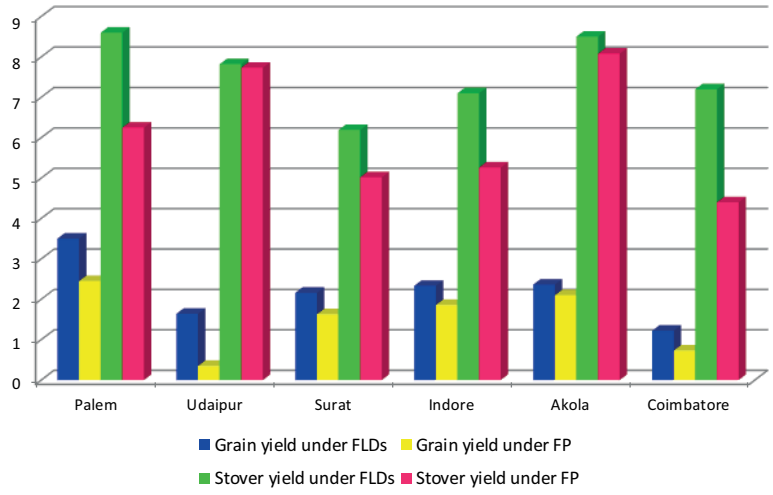


Fig. 2. Performance of latest sorghum cultivars over local (FP) under *kharif* FLDs

Performance of kharif hybrid (CSH 25) under FLDs

3 Post-rainy (*rabi*) sorghum production technologies and their impact

Rabi sorghum is extensively grown in the states of Maharashtra (31.17 lakh ha), and Karnataka (12.90 lakh ha), while to some extant in Telangana state (3.18 lakh ha), Tamil Nadu (3.18 lakh ha) and Gujarat (0.63 lakh ha). From a stabilized area of about 52 lakh ha in India, about 42 lakh tons of sorghum grain is produced with an average productivity of 817 kg ha^{-1} during the *rabi* season. To a greater extant it is grown on stored soil moisture re-filled by the South West monsoon (June-Sept). Productivity of *rabi* sorghum valued for both food and fodder is mainly driven by the water holding capacity of soil. Soil moisture conservation, use of soil-based high yielding varieties and fertilizer management play major role in improving the productivity of rabi sorghum. In certain areas of Maharashtra, the crop is grown in deep soil with 2-5 irrigations with a stable productivity of 4.0 to 5.5 t ha^{-1}.

Selection of high yielding cultivars and hybrids

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

State	Area of adptation	Hybrids	Varieties
Maharashtra	Rain fed areas (Medium to deep soils)	CSH 15R, CSH 19R	CSV 29R, M35-1, CSV 14R, CSV 216R, Parbhani Moti, Maulee, CSV 22
	Irrigated areas	CSH 15R, CSH 19R	Swati, CSV 216R, CSV 18R, PKV Kranti, CSV 22, Phule Vasudha
	Shallow soil		CSV 26R, CSV 18R, Sel.3, Phule Anuradha, Phule Chitra
Karnataka	Dry zones (deep soil)	CSH 15R	CSV 29R, M 35-1, DSV 4
	Transitional zones (médium soil)	CSH 15R	CSV 14R, DSV 5
	Irrigated zone	CSH 15R, CSH 19R	CSV 29R, DSV 5, CSV 18, CSV 22R
Telangana	Telangana	CSH 15R	CSV 29R, CSV 22R, CSV 26R
	Normal rabi areas	CSH 15R	CSV 29R, M 35-1, CSV 26R, CSV 18, CSV 22R
Tamil Nadu	Entire rabi area	CSH 15R	CSV 29R, CSV 26 R, CSV 18R, CSV 22R
	Summer irrigated areas	CSH 15R	Co 26, Co 24, CoFS 29, CSV 33, CSV 31 (Forage Sorghum)
Gujarat	Entire rabi zone	CSH 15R	CSV 29R, CSV 26 R, CSV 18R, CSV 22R

Preparation of land

One deep ploughing with mould 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.

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 : 8-10 kg/ha

Spacing : Row to row 45 cm and plant to plant 15 cm

Plant population : In rainfed conditions - 1.35 lakh per ha.
In irrigated conditions - 1.50 to 1.80 lakh per ha.

Nutrient management

Rainfed (shallow to medium soil) : 40:20:00 Kg NPK ha^{-1} as basal

Rainfed (deep soil) : 60:30:00 Kg NPK ha^{-1} as basal

Irrigated : 80:40:40 Kg NPK ha (N in two equal splits 50% as basal and 50% at 30-35 days after sowing full P & K at time of sowing)

Inter-cultivation and weed control

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

Weed management: Application of Atrazine @ 0.5 kg a.i/ha is recommended for spraying on the soil as pre-emergence application immediately after sowing.

Water management

Under irrigated conditions in medium-deep to deep soils, three irrigations first at germination, next 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 is sown after a fallow period (*kharif)* in medium to deep soil where the rainfall frequency is high. However, double cropping of black gram/ green gram/ cowpea (fodder) and rabi sorghum is recommended wherever found operationally feasible. Soybean + *rabi* sorghum sequence cropping found feasible and profitable in irrigated conditions. Intercropping of sorghum with safflower in 4:2 or 6:3 ratio is recommended in deep soils.

Insect pests and their management

Shoot fly

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.

Management

- Planting towards the September end to October first week is ideal to escape shoot fly damage.
- Increase the seed rate and destroy the 'deadheart' seedlings after removal, to maintain the optimum plant stand
- When planted late, resort to seed treatment with Imidacloprid @14 ml/kg of seed or Thiamethoxam 70 WS @ 3gm/kg of seed.
- Application of Carbofuran 3G at the time of sowing as soil application in the seed furrows @ 20 kg ha^{-1} can effectively check the pest incidence.

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.

Management

- Uprooting and burning of stubbles and chopping of stems prevent its carryover.
- The borer can be controlled by application of any of the insecticides into the whorl such as Carbofuron 3G, @ 8-12 kg ha-1 at 20 and 35 days after emergence.

c) Shoot bug

Heavy infestation is seen on the rabi crop, when rain occurs at seedling stage. The nymph and adults suck the plant sap causing reduced plant vigour and yellowing. In severe cases, the younger leaves start drying and gradually extends to older leaves. Sometimes, complete plant death occurs.

Management

- Alternate host grasses as related should be removed to build-up of shoot bug. Application of Carbofuran 3G or @ 8 kg ha^{-1} in the whorls can effectively check the incidence of the pest.

Shoot bug nymphs & adults

Yellowing of leaves

d) Aphids

Aphids and nymphs prefer to feed leaves. Attack during the boot stage 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 edges. They produce abundant honeydew which predisposes the plant to sooty and other sporadic fungal pathogens. Severe damage under moisture stress conditions resulting in drying of leaves as well as plant death.

Management

- Spraying of Metasystox 35 EC (@ 2 ml/ lt of water effectively controls aphids.

Aphid infested leaf

Diseases and their management

a) Charcoal rot

- 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, paddy straw mulch will provide marginal advantage in checking the disease symptoms
- Seed treatment with talc based farmolation of *Pseudomonas Chlororaphis* @10g/ kg seed reduces the charcoal rot incidence.

Charcoal rot infestation

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 earhead.
- Plants infected at later stages appear dwarf with short internodes, show partial exertion of earhead having few or no seed formations.

Management

- Avoid sowing in early September and October-sowing is recommended to reduce stripe virus disease incidence
- Spraying metasystox 35EC or methyl-S-demeton 35EC @ 5 ml/ 10L water at 15 days interval starting from 20 DAE controls vector and spread of the disease.

Stripe virus infested plant

Pest management

1. Deep ploughing to expose the larval and pupal stages of shoot fly;
2. Early sowing between last week of September to first week of October for escaping shoot fly incidence;
3. High seed rate @ 10 to 12 kg ha^{-1} is recommended in case delay in sowing;
4. Inter cropping of sorghum + safflower (2:1 ratio) in *rabi* season is recommended;
5. Seed treatment with Imidacloprid @14 ml/kg of seed or alternatively Furadon / Carbofuran 50SP@100 g/kg of seed is recommended;
6. Soil application of Carbofuran 3G granules @ 20 kg ha^{-1} in furrows at the time of sowing as prophylactia measure to control shoot pest is recommended;
7. Releasing egg parasite, *Trichogramma chilonis* Ishii @ 12.5 lakh ha^{-1} is recommended to reduce shootfly incidence in *rabi* sorghum.

Harvesting and threshing

Crop should be harvested at physiology maturity (110-120 days after sowing) depending upon the genotypes duration. The harvested panicles are left in the field for about a week for drying and thereafter, the grains are separated from panicles by threshing or manually. The panicles are harvested first and remaining plants latter.

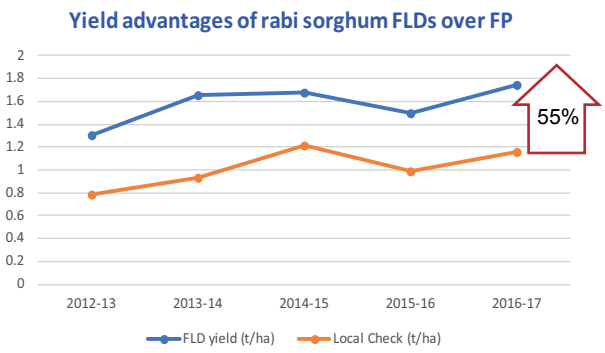
Drying / Bagging

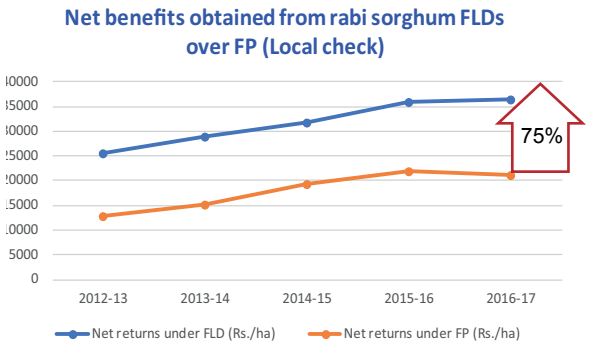
After threshing, the grains are sundried for 1-2 days to reduce the moisture content up to 10-12%. Bagging of the grains is done in plastic or gunny bags for immediate marketing.

Threshing operation

Impact of the technologies

- Although, the area under *rabi* sorghum reduced with little external recently. However, due to concerted efforts made by the scientists, extension workers, developmental; agencies and farmers, average productivity has now increased.
- More than 1000 FLDs were organized between 2012-13 and 2016-17 with Improved *rabi* sorghum cultivars namely, CSV 26R, CSV 29R, CSV 18R, CSV 22R, PKV Kranti, Phule Vasuda, Phule Yashodha, Phule Revati, Phule Chitra, Parbhani Moti and Parbhani Jyoti (CSV 18R) in major sorghum growing states Maharashtra, Karnataka and Andhra Pradesh. They gave additional 55% grain and 49% stover yields than the local checks (FP) and obtained 75% more net returns than the local cultivars as shown tin the following figure.





Field view of local variety (left) and high yielding variety under FLD (right)

4 Sorghum production technologies for rice fallows under zero-tillage

Despite of multiple uses of sorghum 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 5.65 m ha in 2015-16. In rice-fallows of coastal Andhra Pradesh, sorghum cultivation is gaining popularity among farmers due to its high productivity (6.8 t/ha in 2014-15) whereas, the national productivity is very low (average yield is below 1.0 t /ha) as indicated in Fig. 3. The farmers are commercially motivated and selected to grow sorghum instead of maize on residual moisture of rice-harvested field without tillage condition 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 other benefits. Keeping these in view, proven hybrid along with package of practices were demonstrated in several farmers' fields which are further being disseminated in the Guntur district. Of late, sorghum is being cultivated in rice-fallows after harvesting of paddy on residual 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, Haritha, Kaveri, Mahyco 51 and Mahalaxmi 296. However, the experimental trials ascertained that hybrid CSH 16 yielded substantially higher grain up to 8.00 t/ha than 17 public and private cultivars. It has medium plant height and found suitable for the rice-fallows situations. The concomitant increase in average sorghum productivity of Guntur district is witnessed (Fig. 2). Five major cultivation practices suitable for rice-fallows area were evaluated and validated in farmers' fields. These are the documented for ready reference to new farmers.

Suitable hybrids

CSH 16		
Year of release	:	1997
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 mould and resistant to leaf spot disease and lodging, easily digestible fodder for cattle

CSH 14		
Year of release	:	1992
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

- Put 3-4 seeds in each hole at 4 cm - 6 cm depth @ 7-8 kg seeds per ha (3 kg/ acre)

Seed treatment

- Before sowing, treat sorghum seeds with 14 ml Imidacloprid + 2 g Carbendazim (*Bavistin*) for one kg of the seed, or Thiomethaxam @ 3 g/kg of seeds

Spacing

- Row to row 45 cm and plant to plant distance 10 to15 cm
- Maintain plant population as 1,80,000 plants per ha (72,000 plants per acre)

Fertilizers application

- **First dose of fertilizers:** Half dose of Nitrogen i.e., 40 kg per ha, full dose of P_2O_5 i.e, 40kg per ha and full dose of K_2O i.e, 40 kg per ha at sowing. Apply basal fertilizers in each hole at 6-8 cm at the time of sowing and cover it with pinch of soils before sowing the seeds.
- **Second dose of fertilizers:** Apply half Nitrogen 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 the genotypes duration. The harvested panicles are left in the field for about a week for drying and thereafter the grains are separated from panicles by threshing or manually. The panicles are harvested first and remaining plants latter.

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.

Impact of proven technologies

Taking advantage of residual moisture, saving in cost of land preparation, judicial use of seeds, limited irrigation water and weed management have shown positive change in attitude of farmers. In view of increasing popularity of sorghum cultivation in

Field view of CSH 16

rice-fallows in Guntur district of Andhra Pradesh, many field demonstrations on promising sorghum hybrid CSH 16 were organized on large scale to popularize the technology.

Results of 126 frontline demonstrations (FLDs) organized during 2011-12 revealed that CSH 16 (8.62 t ha^{-1}) yielded significantly better than the locally popular hybrid, 'Mahalaxmi 296' (6.06 t ha^{-1}). Moreover, the significant increase of 42% was observed with CSH 16 over check Mahalaxmi 296. The increase in grain yield was due more grain weight per panicle and number of panicles per unit area. Though, the fodder was not much important to the farmers of this area, the same trend of fodder yield was also recorded from CSH 16 (12.50 t ha^{-1}) and Mahalaxmi 296 (7.90 t ha^{-1}). On an average, the demonstrated hybrid CSH 16 under FLDs in rice-fallows gave 68% higher net returns (Rs.57,500/- per ha) than the check Mahalaxmi 296 (Rs.31,900/- per ha) with a cost of cultivation Rs.28,700/- per ha.

The preliminary studies indicated that the farmers were interested in grain sorghum only because they found only marginal difference between price of sorghum (Rs. 1200/- to 1500/- per 100 kg) and maize (Rs. 1300/- to 1800/- per 100 kg). Another important motive was, a short duration crop like, sorghum (110-120 days) is suitable to fit in the crop rotation and fifth motive was, less insect-pest problems in sorghum compared to other crops. Hence since last 6-8 years, farmers are adopting improved sorghum cultivation after harvest of rice on the residual soil moisture under zero-tillage.

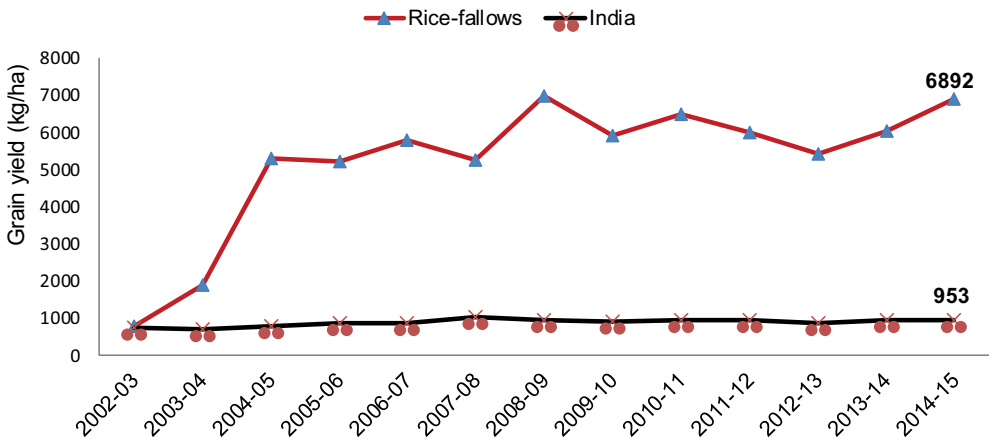


Fig. 3. Productivity of sorghum in rice-fallows in Guntur district and national average

5 Forage sorghum production technologies and their impact

Sorghum is an ideal forage crop due to its quick growth, lower water requirement, high yielding ability (350-400 q/ha and 700-750 g/ha of green fodder from single cut and multi-cut varieties/hybrids, respectively), high dry mater content (25-30%), better quality (crude protein 5-9%) and its suitability for various forms of utilization like green chop, silage and hay. The stage of maturity is the most important factor influencing the quality and quantity of forage produced. Maximum green fodder with highest nutritive value is obtained at 50 per cent flowering stage.

Different types of forage sorghum

The most fundamental management decision a forage sorghum producer makes is how the forage will be utilized, which in turn affects the type and variety of forage sorghum to grow. There are different types of sorghum, which are in use in some form either in our country or in western countries that can be regarded as forage sorghum. In India, single-cut, multi-cut and dual purpose genotypes are popular. The main types of forage

sorghums are sudan grass varieties, sudan x sudan grass hybrids, grain sorghum x sudan grass hybrids, grain sorghum x grain sorghum hybrids and dual purpose varieties. In general, in the northern belt, sudan grass varieties and grain sorghum x sudan grass hybrids are popular.

Humidity : 80-85% relative humidity is suitable for crop growth in *kharif*

Rainfall : 500-750 mm average rains

Optimum temperature : 33-34^{0}C in Kharif for good growth, Above 24-25 ^{0}C during *rabi,* Optimum soil temperature 18-21 ^{0}C for good germination

Soil requirements

Topography : Leveled and well drained land are preferred

Texture : Loam, sandy loam, light and average black soil with good drainage are suitable

pH : 6.5 to 7.5 pH is optimum for good plant growth

Varieties

The list of improved and popular varieties recommended for different states are given below.

Sl. No.	State	Single cut varieties	Multi-cut hybrids	Multi-cut varieties
1.	All States	PC 1, HC 136, UP CHARI 1, PUSA CHARI 9, RAJASTHAN CHARI 1, UP CHARI 2, HC 260, HC 171, RAJASTHAN CHARI 3, HC 308, PCH 106, PANT CHARI 5, CSV 30F, CSV 21F	CSH 20MF, CSH 24MF	SSG 59-3 MP CHARI, Pusa Chari 6, PUSA CHARI 23, CSV 33 MF
2.	Haryana	JJ 20, JS 263, JS 29-1, HJ 513, HJ 541		
3	Punjab		Punjab Sudex Chari 1, Punjab Sudax Chari 4	SL 44
4.	Tamil Nadu	K1, K7, CSV 32F		Co(Fs) 29

5.	NCR Delhi		Pusa Chari Hybrid 109	Pusa Chari 615
6.	Gujarat	GFSH 1, GFS 5		GFS-4
7.	Rajasthan	Pratap Chari 1080		
8.	Uttarakhand	Pant Chari 7		Pant Chari 6 Pant Chari 8
9.	Maharashtra	Ruchira, CSV 32F		
10.	Uttar Pradesh	Pant Chari 3		
11	Karnataka	CSV 32F		

a. Field preparation and sowing

One summer ploughing followed by 2-3 harrowings and planking are required for making the land powdery/clump free. Sowing time of sorghum depends upon 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 multicut varieties/hybrids should be sown in first fortnight of April. The planting time can be extended upto first week of May depending upon the availability of land and irrigation. Usually, the onset of monsoon or second week of June is suitable for single cut forage sorghum.

Multi-cut forage sorghum

Seed rate : 10 kg/ha

Spacing : 45 cm between rows

Time of sowing : April – Mid May

Fertilizers : 60 kg N/ha and 60 kg P_2O_5/ha as basal. Top dressing with 40 kg N/ha after each cut

Irrigation : As and when required or at 7 to 10 days interval in summer season.

Single-cut forage sorghum

Seed rate : 25 kg/ha

Spacing : 30 cm between rows

Time of sowing : June (with onset of monsoon)

Fertilizers : 80 kg N in 2 split doses one at basal and the other at 30 DAS + 40 kg P_2O_5/ha

Method of sowing

For proper germination seed should be sown at a depth of 2.5-4 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 application 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 an adequate moisture in the soil.

Integrated nutrient management

- 10-15 ton/ha Compost or FYM before sowing
- 35-45 kg Nitrogen/ha to be applied 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 multicut sorghum

Irrigation / water management

Generally, sorghum crops 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

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 sowing (within 48 hrs.), and it needs to be ensured that the soil surface is moist.

Common weeds

- Motha - *Cyperus rotundus*
- Doob -*Cynodon dactylon*
- Other broad leaved weeds

Integrated weed management

- Summer ploughing
- Well prepared land
- 1-2 hand weedings
- Use of optimum seed rate with seeds having good germination percentage

Crop systems

Mixed cropping

Planting of legumes like cowpea, cluster been (guar), green gram, black gram or pigeon pea 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 berseem and lucern. It saves nitrogen application to sorghum crop. Popular crop rotation with fodder sorghum includes:

- Fodder sorghum-Berseem-Maize + Cowpea (one year)
- Fodder sorghum-Oat- Maize + Cowpea (one year)
- Maize (grain)-Wheat-Fodder sorghum + Cowpea (two years)
- Fodder sorghum-Pea (grain)-Sugarcane (two years)

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 400-450 q/ha whereas multi-cut varieties/hybrids may yield 600-900 q/ha green fodder in 3-4 cuts if sowing is done during March (end) – April (first week)

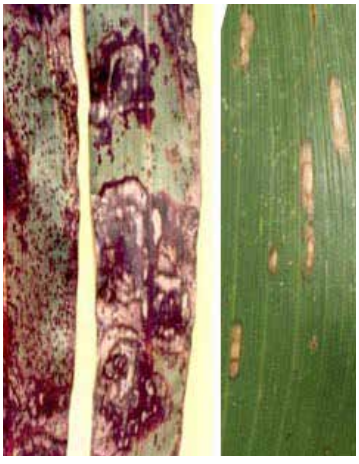
Gray leaf spot & Zonate

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 food for cattle at flowering/ 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.

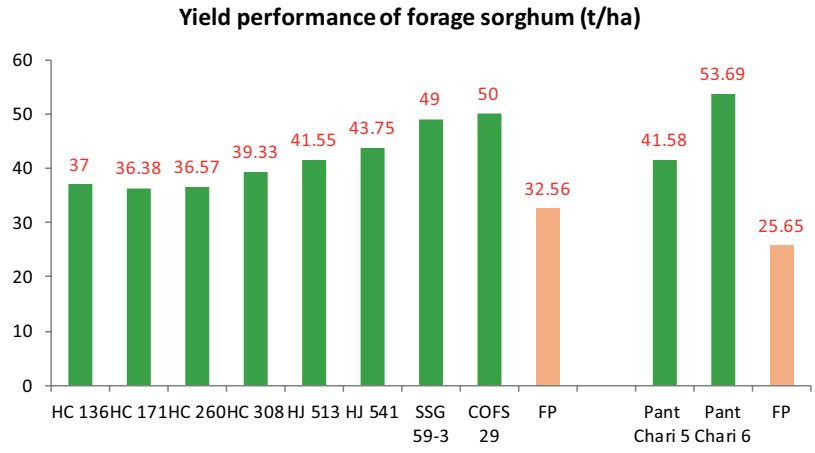


Anthracnose

Impact of the technologies

Improved forage cultivars; HC 136, HC 171, HC 260, HC 308, HJ 513, HJ 541, SSG 59-3 and CoFS 29 performed better in terms of green fodder yield under FLD in Nuh, Hissar district, Pilani, Kaithal, Yamunanagar and Kurukshetra district in Hissar State during 2016-17.

The single and multi-cut FLD cultivars gave 10% green fodder yield and net returns than the local check, as shown in the following figure. Performance of forage cultivars; Pant Chari 5 and Pant Chari 6 was found better in terms of green fodder yield among the demonstrated cultivars in Udham Singh Nagar district in Uttarakhand State during 2016-17, as shown in the following figure. The forage cultivars under FLD gave 21% higher green fodder yield than the local check, which was resulted into 40% more net returns.



6 Pearl millet (*bajra*) production technologies and their impact

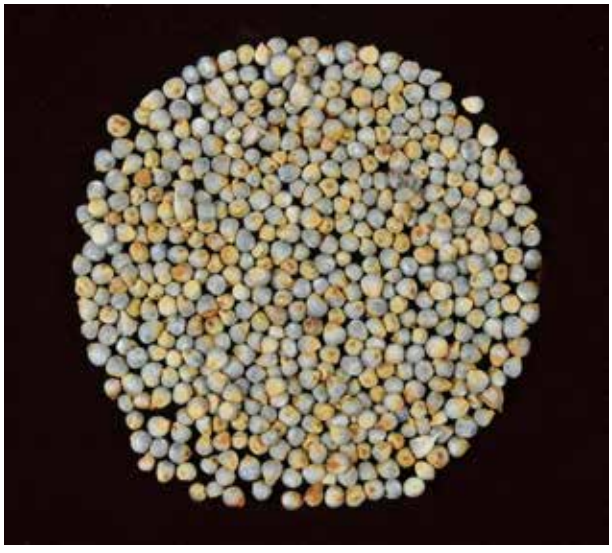
Pearl millet

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

Common name: Bajra

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

Family: Gramineae



In India, pearl millet is the fourth most important cereal crop after rice, wheat and maize. It was cultivated in 6.98 m ha and produced 8.06 m tons with an average productivity of 1154 kg/ha during 2016. In India, around 58% of pearl millet area is grown in Rajasthan, contributing 44% of total production followed by Uttar Pradesh as indicated in the Table on the next page. Pearl millet is an important crop that reliably produces food and fodder for millions of people where the growing conditions are too dry and too infertile to grow most other grain crops. Although the grain is used mainly as a human food crop, it is also used to feed livestock. Additionally, the plant is used for grazing, hay, silage, as

building material, and as a source of fuel. Pearl millet forage is highly digestible in the vegetative stage and does not produce hydrocyanic acid (HCN). It is high in oil, protein, and energy, has balanced amino acids (except low in S-containing amino acids), is high in Ca and Fe, and contains no tannins. Pearl millet is consumed in many different ways: porridges, breads, fermented and nonfermented beverages, snacks, popped grain, etc.

Area, Production and Yield of pearl millet during 2014-15 and 2015-16 in major Producing States along with coverage under Irrigation

State	Area (m ha)	% to All India	Production (m tons)	% All India	Yield (kg/ha)	Area under irrigation (%) 2013-14)
Rajasthan	4.04	57.92	3.53	43.78	872	3.4
Uttar Pradesh	0.98	13.96	1.78	22.03	1821	10.7
Gujarat	0.39	5.64	0.79	9.8	2004	22.3
Haryana	0.37	5.3	0.65	8.09	1762	42.2
Madhya Pradesh	0.27	3.82	0.59	7.3	2203	0.1
Maharashtra	0.64	9.15	0.34	4.19	529	5.0
Tamil Nadu	0.06	0.81	0.15	1.84	2613	15.4
Karnataka	0.17	2.41	0.15	1.82	875	11.9
Andhra Pradesh	0.04	0.53	0.07	0.81	1757	22.1
Jammu & Kashmir	0.02	0.24	0.01	0.12	597	4.1
Telangana	0.01	0.09	0.01	0.07	1000	67.5
Others	0.01	0.13	0.01	0.13	-	-
All India	6.98	100	8.06	100	1154	9.0

Source: Directorate of Economics and Statistics, DAC&FW, Status arranged in descending order of their percent share of production

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 cultivars

Most of the pearl millet area is grown with hybrids while the varieties are preferred in drought prone ecologies. The improved list of hybrids and varieties of pearl millet is given on the next page.

Region/ State	Crop season	Hybrid	Recommended Variety
Rajasthan	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	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
Gujarat	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	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
Haryana	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	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	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	PCB 164, ICMV 221, Raj 171
Delhi	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171
Uttar Pradesh	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171
Madhya Pradesh	Kharif	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 4, JBV 3, PC 383, ICMV 221, Raj 171
Maharashtra	Kharif	Kaveri Super Boss, Pratap, PKV Raj, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	ABPC-4-3, PC 612, Parbhani Sampada, Samrudhi, ICMV 221, Raj 171, ICMV 155
	Summer	Nandi 70, Nandi 72, 86M64	
Tamilnadu	Kharif	Kaveri Super Boss, Pratap, Co 9, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	PC 612, CoCu 9, Samrudhi, ICMV 221, Raj 171, ICMV 155
	Summer	Nandi 70, Nandi 72, 86M64	
Andhra Pradesh	Kharif	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, 86M86, PAC 909, 86M64, 86M53	PC 612, Samrudhi, ICMV 221, Raj 171, ICMV 155

Method of sowing

Three systems of pearl millet sowing are followed: (1) on a flat surface, or (2) using ridge and furrow system, or (3) 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 Tamil nadu. 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 5 standard Meteorological Week (SMW) i.e. last week of January to 1st week of February to obtain higher production of summer pearl millet.

Seed treatment

Seed treatment with biopesticides (*Trichoderma harzianum* @ 4g kg^{-1}) or thiram 75% dust @ 3 g kg^{-1} seed will help against soilborne diseases. Seed treatment with 300-mesh sulfur powder @ 4 g kg^{-1} 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^{-1} 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 1.00 to 1.25 lac/ha. For the area receiving rainfall more than 450 mm (zone A & B), the crop should be planted at the spacing of 45 x 10-15 cm keeping plant population of 1.75 to 2.0 lakhs/ha.

Seed rate for the crop should be taken @ 3 to 4 kg/ha for obtaining required plant stand. The recommended plant stand for pearl millet under normal conditions is 180,000 plants ha^{-1} or 72,000 plants $acre^{-1}$. Under irrigation or high levels of management on highly productive soils, a population of 225,000 plants ha^{-1} (100,000 plants $acre^{-1}$) is recommended. On extremely sandy, droughty soils, a population of about 90,000 plants ha^{-1} (40,000 plants $acre^{-1}$) is desirable.

Nutrient management

Application of 40 kg N + 20 kg P_2O_5/ha for arid regions and 60 kg N/ha + 30 kg P_2O_5/ha for semi-arid regions is recommended for sole pearl millet as well as intercropping system. In light soils (sandy loams) the applied nitrogen may be lost due to leaching with heavy rains. So, only about half of the recommended nitrogen dose should be applied at seedbed 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 (*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 10 kg $ZnSO_4$/ 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 nitrogen @ 20 kg/ha should be given.

Inter-cultivation and weed control

Two hoeings and weedings at 15 and 30 DAS are sufficient for controlling weeds effectively which is comparable with the herbicidal weed control through pre-emergent application of Atrazine @ 0.5 kg/ha superimposed with one hand weeding. Second weeding helps to conserve soil moisture.

Pearl millet-based cropping systems in *kharif*

Rotation of cultivars also should be adopted to avoid downy mildew disease problem. Pearl millet hybrids and open-pollinated varieties should be

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 + Moth bean / Pigeonpea/soybean/blackgram, greengram/cowpea/sunflower
Karnataka	Pearl millet + Pigeonpea greengram/sunflower/soybean
Tamil Nadu	Pearl millet + Pigeonpea greengram/sunflower/soybean/cowpea
Andhra Pradesh	Pearl millet + Pigeonpea/ greengram/sunflower/soybean/ groundnut

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. The pearl millet based croppings are followed in the difference states of the country as given in the Table on previous page.

Irrigation

Under prolonged dry spells, irrigation should be applied 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 (0.75-1.0IW/CPE with 40 mm) as per need of the crop.

White grub

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 States. 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.

Adult beetle

Management

- 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
- Mixing of *Carbofuran* 3G @ 12 Kg/ha with *Bajra* seed and application in seed furrows at the time of sowing is effective

Damaged seedlings

- Soil drenching of Imidacloprid 17.8 SL @ 300 ml/ha or Chlorpyriphos 20 EC or Quinolphos 25 EC @ 4 liter/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

A common pest of Gujarat and Tamilnadu State. 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.

Management

- The crop should be sown with the onset of the monsoon or Improved within 10-15 days of first shower of monsoon;
- Staggered sowing to contain the buildup of shoot fly population
- 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.
- 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 feed on foliage, at times causing severe defoliation of the crop; adults are short winged and can fly short distances only.

Management

- Weed free cultivation; deep summer ploughing after harvest of the crop to expose "egg pods" in soil
- Scrapping of bunds and clean cultivation
- Dust the crop with 4 % cypermethrin or Fenvalerate dust @25 kg/ha or spray the crop with 0.07% of cypermethrin.

Grass hopper

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

Management

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 chlorpyriphos 5 D @ 35 kg/ha at the time of sowing. When the incidence of pest is noticed in standing crop dilute chlorpyriphos 20EC in 5 L of water and mix it with 50 kg of soil and broadcast evenly in 1 ha followed by light irrigation.

Termite damaged crop

Grey weevil

A polyphagous insect. Adult beetles feed on green leaves, cause serious damage when seedlings are infested.

- Dusting of *Quinalphos* 1.5% or *Methyl Parathion* 2% or *Malathion* 5% @ 25 kg/ha on appearance of the pest

Grey weevil

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.

Shrivelled grains

Management

- Early planting reduces the infestation of the pest, application of Carbaryl 50 SP @ 3 Kg in 500 litre of water/ha

Earhead bug

Stem borers

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

Management

For stem borers, Carbofuran 3G granules may be applied in the whorls @ 8 – 12 kg ai/ha or the entire field can be sprayed with Metasystox @ 2 ml / liter.

Major diseases

Downy mildew

- Leaf symptoms begin as chlorosis at the base of the leaf lamina and successively higher leaves show the symptoms.
- Infected leaf area produce massive amount of asexual spores, generally on the lower surface.
- Systemically infected plants remain stunted either do not produce panicle or produce malformed panicles.

Downy mildew infested plants

Management

- Use of resistant cultivars
- Rotate hybrids with variety alternately to keep soil inoculum under control.
- Seed treatment with Apron 35 SD @ 6g/kg seed
- Seed treatment with *Bacillus pumulis* (INR7)
- Foliar spray of Ridomil 25% WP (100 ppm) after 21 days of sowing if infection exceeds 2-5 %

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 infested plants

Management

- Use of resistant hybrids/verieties.
- Sow the crop with the onset of monsoon.
- Destruction of collateral hosts like Ischaemum pretosum and Panicum maximum on the field bunds.
- Spraying of Dithane M 45 @ o.2% thrice commencing from 1 month old crop onwards at 10 days intervals

Smut

- 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.

Management

- Use of resistant cultivars.
- Seed dressing with Thiram 75 @ 3 gms/kg seed.
- Remove smutted ears from the field covering in a plastic bag.

Ergot

- A honeydew like creamy to light pinkish ooze comes out of the infected florets which contains numerous conidia.
- A hard dark black structure (sclerotia) larger than seeds protrudes out from the florets in place of grain.
- 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% @ 0.2% starting from 50% flowering reduce incidence.

Blast

- The symptoms appear as distinct large, indefinite, water soaked, spindle shaped, lesions
- Center of the lesion grey and purple grey horizon with yellow margin
- Severe infection resulting in extensive chlorosis and premature drying of young leaves.

Blast infestation

Management

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

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 12%.

Threshing, cleaning, drying and storing

Dry the earheads. Thresh in a mechanical thresher or spread it and drag a stone roller over it or cattle threshes. Dry the seeds below 10 per cent and mix 100 kg of grains with 1kg of activated kaolin to reduce the rice weevil and rice moth incidence. Spray Malathion 50EC 10 ml/ lit @ 3 lit of spray fluid/100 m^2 over the bags during storage godowns. For grain purpose the grain should be dried well below 10% moisture and stored in gunny bags.

Field view of GHB 538

Field view of HHB 67

7 Finger millet (*ragi*) production technologies and their impact

Finger millet

(*Eleusine coracana* L.)

Common name: *Ragi*

Vernacular names: Finger millet (English), Ragi, Mandua, Nagli, Nachani (Marathi) and kapai

Family: Gramineae

Finger millet is important small millet grown in India. It is a staple food in many hilly regions of the country. It is grown both as grain and forage. Grains are rich in minerals and are the richest source of calcium used in many preparations like, cakes, puddings, sweet etc. The green straw is suitable for making silage. It is also good for persons suffering from diabetes.

Climate

Finger millet is a crop of tropical and subtropical climate and can be cultivated up to an altitude of 2100 m. It is heat loving plant and for its germination, the minimum temperature required is 8-10 ^{0}C. A mean temperature range of 26-29 ^{0}C during the growth is the best for proper development and good crop yield.

Soil

Finger millet can be grown on a wide range of soils from very poor to very fertile and can tolerates a certain degree of alkalinity. The best soil is alluvial, loamy and sandy soil with good drainage.

Varieties

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

S. No.	State	Varieties
1.	Karnataka	GPU 28, GPU-45, GPU-48, PR 202, MR 1, MR 6, Indaf 7, ML-365, GPU 67, GPU 66, KMR 204, KMR 301, KMR 340, DHFM-78-3
2.	Tamil Nadu	GPU 28, CO 13, TNAU 946 (CO 14), CO 9, CO 12, CO 15
3.	Andhra Pradesh	VR 847, PR 202, VR 708, VR 762, VR 900, VR 936, PPR-2700
4.	Jharkhand	A 404, BM 2, VL-379
5.	Orissa	OEB 10, OUAT 2, BM 9-1, OEB 526, OEB-532
6.	Uttarakhand	PRM-1, PRM-2, VL 315, VL 324, VL-352, VL 149, VL 146, VL-348, VL-376, PES 400, VL-379
7.	Chattisgarh	Indira Ragi-1, Chhattisgarh-2, BR-7, GPU 28, PR 202, VR 708 and VL 149, VL 315, VL 324, VL 352, VL 376, OEB-526, OEB-532
8.	Maharashtra	Dapoli 1, Phule Nachani, KOPN 235, KOPLM 83, Dapoli-2
9.	Gujarat	GN 4, GN 5, GNN 6, GNN-7
10.	Bihar	RAU 8, VL-379, OEB-526, OEB-532
11	Madhya Pradesh	GPU 28, PR 202, VL 352, VL 376, VL-379

Land preparation

One deep ploughing with mould board plough. Followed by ploughing with wooden plough in the month of April or May twice is necessary. Before sowing, secondary tillage with cultivator using multiple tooth hoe to prepare smooth seed bed is necessary for land preparation. 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, land preparation helps in better germination, minimization of weeds 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

a) Summer ploughing or ploughing after the harvest of previous crop

b) Ploughing across the slope

c) Errection of small section bunds at an interval of 10-12m depending on the slope and levelling the depressions

d) Opening a dead furrow at 3.3 to 4.0 m interval.

Seed rate: 8-10 kg/ha (line sowing)

4 kg/ha (transplanting)

A seed rate of 10 kg ha^{-1} is found to be optimum for drill sowing and 5 kg ha^{-1} for raising seedlings for transplanted condition.

Seed treatment: Seed treated with thiram @ 2.5 g/kg of seed.

Sowing time: Kharif- June to July

Rabi- September to October

Summer-January to February

Method of sowing

Line sowing and transplanting

Line sowing is beneficial, helps in inter cultivation and controls weeds effectively. Maintenance of optimum plant population of 4-5 lakh plants ha^{-1} is important. This 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 in irrigated condition.

Nursery management

An area of 150 m^2 is required to raise seedlings for planting 1 ha. 35-38 beds of 4 feet wide and 25 feet long and 4 inches height fine seed bed is required. Apply 2-3 baskets of well decomposed farm yard mannure (FYM) along with 1 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. Treating seeds with *Azospirullum brasilense* (nitrogen fixing bacterium) and *Aspergillus awamouri* (phosphate solubalizing fungus) @ 25 g kg^{-1} is beneficial.

Spacing and fertilizers: Row to row 22.5 to 30 cm, plant to plant 10 cm and depth 3-4 cm.

Application of addition 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 about a month before sowing. The crop responds well to fertilizer application. The general recommendation for finger millet is 60 kg nitrogen, 30 kg P_2O_5 and 30 kg K_2O per hectare under irrigation and 40 kg nitrogen, 20 kg P_2O_5 and 20 kg K_2O per hectare under rainfed conditions. State-wise spacing and fertilizers recommendations are given in the following Table.

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

Entire P_2O_5 and K_2O are to be applied at sowing, whereas nitrogen 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 nitrogen 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

1. Bio-fertilizer culture specific to the crop is to be used @ 25g/kg of seed.
2. 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.
3. 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.
4. The culture-coated seed is to be dried well in shade to avoid clumping of seeds.
5. Use the inoculated seeds for sowing.

Irrigation management

Finger millet sown during kharif generally does not need any irrigation. There are two critical growth stages for irrigation namely, tillering stage and flowering stage. If rains stop for longer spell, then irrigation would be required to obtain good yield. Depending on soil type, weather condition and duration of variety, 8-14 irrigation are necessary.

Light soils: Irrigate the crop once in 6-8 days

Heavy soils: Once in 12-15 days.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enchinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica* (kodo), *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 stage of plant growth and development. The inter-cultivation and weeding should be done with hand hoe at 25 days after sowing. Weeds problem in ragi crop can be effectively managed by cultural and mechanical measures.

Line sowing: 2-3 inter cultivations and one hand weeding

Broadcast crop: 2 effective hand weeding will minimize weeds

In assured rainfall and irrigated areas: Pre-emergence spray: Isoproturon @ 0.5 kg a.i./ha. (Rainfed areas), Oxyflurofen @ 0.1 lt a.i /ha (Irrigated areas)

Post-emergentce spray: 2, 4-D sodium salt @ 0.75 kg a.i./ha. Spraying around 20-25 days after sowing effectively control weeds.

Inter-cropping

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

Crop Rotation

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

Southern states

a. Horse gram, pigeon pea, field bean or ground nut

b. This practice will minimize inorganic fertilizer application and also sustain higher yields.

c. 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.

Insects 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 important.

Army worms and cut worms

They appear during the early stages and continue upto 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.

Management

- Dusting of Malathion 5% @ 24 kg/ha or Quinolphos 1.5% @ 24 kg/ha when symptoms are noticed.
- Apply poison baits comprising 10 kg rice bran + 1 kg jaggery + one liter Quinolphos (25 % EC). Prepare small balls broadcast in the fields preferably in the evening times.

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 upto 30 days.

Management: Spraying of Dimethoate (0.05%) or Quinalphos (0.05%) give effective control.

Stem borer

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

Management: Spraying the crop with Metasystox 0.07% 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.

Management: Dust Malathion 5% @ 24 kg/ha or Quinolphos 1.5% @ 24 kg/ha or

Diseases

Blast

- Diamond shaped lesions with gray center and dark margin appears on the leaf,
- Any plant part including leaves, peduncle, and grains can be infected.
- Grains of infected earheads are shrivelled and become light in weight.

Blast infested plant

Management

- Use of disease resistant varieties.
- Treating seeds with fungicides like carbendazim @ 2g/kg a day before sowing
- If necessary spraying the nursery with carbendazim (0.05%) or kitazin (0.1%)
- Spray any of the above fungicides at 50 per cent flowering and repeat 10 days later if Kitazin was used 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.

Management

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

Harvesting

The crop matures in about 95 to 110 days for early varieties and 115 to 125 days for medium to late duration varieties depending on the tract 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.

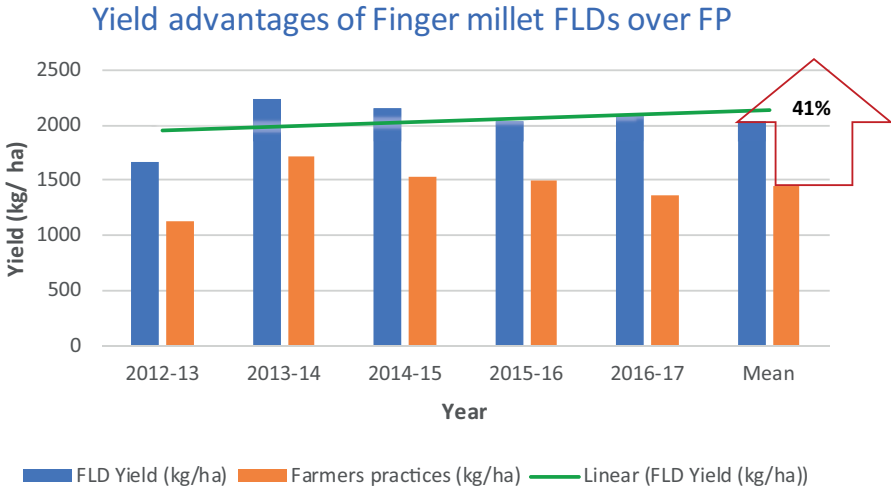
Yield

It is possible to harvest 25-30 quintal/ha of grain and 60-70 quintal/ha of fodder. The straw of finger millet makes nutritious fodder. It can be conserved by putting up in well-built stakes.

Impact of the technologies

The demonstrated varieties of finger millet in farmers' field exhibited an overall 41% improvement for grain yield during the last five years (2012-13 to 2016-17) with average productivity of 2040 kg/ha under in FLDs over 1448 kg/ha in farmers practice as mentioned in below figure.

This is mainly due to the demonstration of improved varieties like, GPU-28, GPU-48, GPU-67, ML-365, MR-1, MR-6, KMR-301 (Karnataka), VL-315, VL-324, VL-347, VL-352 (Uttarakhand), RAU-8 in Bihar, Chhattisgarh-2 in Chhattisgarh, VR-847in Andhra Pradesh in FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states. In Karnataka itself, which occupies 70% of area in finger millet, the variety GPU-28 is being cultivated by farmers over 60% of the area in the state.



8 Foxtail millet production technologies and their impact

Foxtail millet

(*Setaria italica* L.)

Common name: Kakun

Vernacular names: Foxtail millet (English), Kangni (Hindi), Navane (Kannada), Thinai (Tamil), Kang (Gujarati) and Rala (Marathi).

Family: Gramineae

Foxtail is also known as italian millet and german millet. It is generally grown as a rainfed crop in India. It has an erect leafy stem that grow 60-75 cm tall and bend quite a bit at maturity due to heavy weight of earhead. Foxtail grain contains 10% to 12% Protein, 4.7% fat, 60.6 % carbohydrates 2.29% to 2.7% Lysine and 0.59 (mg) Thiamin.

Climate and soil

Foxtail can be grown in tropics as well as temperate regions both under low and moderate rainfall. It can be grown even at an altitude of 2000 m and 50-75 cm annual rainfall. It grows well on well-drained loamy soils. They will not tolerate water-logged soils or extreme drought.

Varieties

The list of Improved and popular varieties recommended for different states are given on the next page.

Sl. No.	State	Varieties
1.	Andhra Pradesh	SiA 3088, SiA 3156, SiA 3085, Lepakshi, SiA 326, Narasimharaya, Krishnadevaraya, PS-4
2.	Karnataka	SiA 326, HMT 100-1 and PS 4,Narasimharaya, SiA 3088, SiA 3156, SiA 3085, DHFt-109-3, PS-4
3.	Tamil Nadu	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 (SR 1) and SR 51, SR 11, SR 16, SiA 3085, SiA-3088, SiA-3156, PS-4
5.	Uttar Pradesh	PRK 1 and PS 4, SiA 3088, 3085, Sreelaxmi, Narasimharaya, S-114, SiA 326, PS-4
6.	Uttarakhand	PS 4 and PRK 1, Sreelaxmi, SiA 326, SiA 3088, SiA 3156, SiA 3085, PS-4
7	Bihar	RAU-1, SiA 3088, SiA 3156, SiA 3085, PS-4

Land Preparation

Foxtail millet does not require much field preparation. Before the onset of monsoon, the field should be ploughed once with mould 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

- August – September in Tamilnadu.
- July-August in Karnataka.
- First fortnight of July in Andhra Pradesh.
- Second and third week of July in Maharashtra.
- In Tamil Nadu, *Kharif* irrigated crop is planted from the beginning of June to end of July and summer irrigated crop in January
- Plains of Uttar Pradesh and Bihar, middle of June.

Sowing time: *Kharif*- June to July

Rabi- September to October

Seed rate: 8-10 kg/ha (line sowing)

15 kg/ha (broadcasting)

Seed treatment: Seed treated with Ceresan @ 3 g/kg of seed

Method of Sowing: Broadcasting and line sowing

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

Manures and fertilizers

The crop is usually manured with 5 to 10 t/ha farm yard mannure about a month before sowing. Generally fertilizer recommendations to get a good crop are 40 kg nitrogen, 20 kg P_2O_5 and 20 kg K_2O per hectare. All the fertilizers should be applied as a basal dose at a time of sowing. Fertilizer required for different states is as follows. Soil test - based fertilizers applications is recommended.

State	Fertilizer recommended NP (kg ha^{-1})
Andhra Pradesh	40:30:0
Jharkhand	40:20:0
Karnataka	30:15:0
Maharashtra	20:20:0
Tamil nadu	40:20:0
Other regions	20:20:0

Apply entire quantity of phosphorus and half of nitrogen at sowing and remaining half of nitrogen at 30 days after sowing.

Water management: This crop is 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* (kodo), *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 sowing
- Two hand weeding in broadcasted crop
- Post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS. Isoproturon @ 1.0 kg a.i. /ha as pre-emergence spray is also effective in weeds control.

Inter cropping

Andhra Pradesh: Foxtail millet + ground nut (2:1 ratio)

Foxtail millet + cotton (5:1 ratio) - Royal seema regions.

Finger millet + pigeon pea in 5:1 row ratio.

Relay cropping

Andhra Pradesh: If monsoon is early, sow foxtail millet at 45 cm row spacing and introduce *rabi* jowar 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 one crop of foxtail millet.

Insect-pests and their management

Shoot fly

Apply Carbofuran (Furadan) 3% granules @ 30 kg/ha in furrows or as broadcast before sowing or Phorate @ 15 kg/ha (10% granules) in the soil at the time of field preparation,

Diseases

Downy mildew

- Diseased plants are dwarfed with excessive development of tillers.
- Lengthwise yellow- green streaks are seen on the leaves.

Management

Spray of Ridomil-MZ@3 g/L water may help to control the disease and seed treatment is also helps in controlling the disease.

Harvesting time

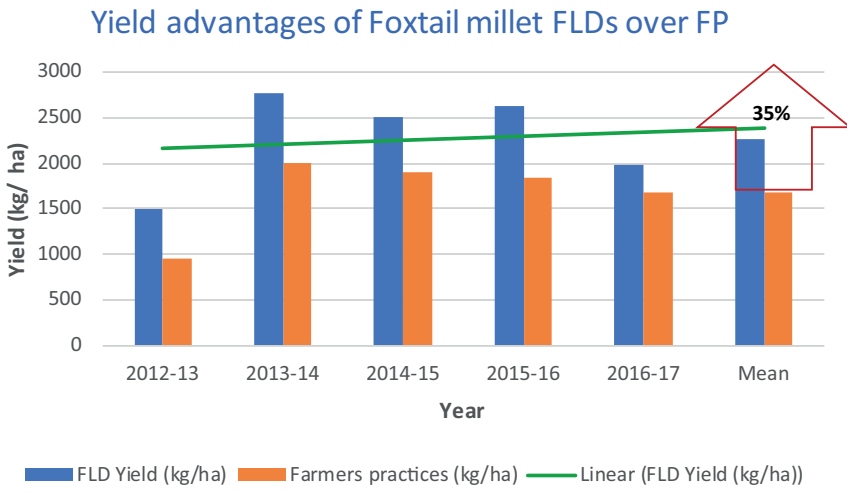
The crop matures in 80-100 days. The crop is harvested when the earheads are dry, either by cutting the whole plant by sickle or the earheads separately. The crop is usually harvested during *kharif* season from September to October and *rabi* season from January to February.

Yield: Grain-15-18 quintal/ha and straw-20-40 quintal/ha.

Impact of the technologies

There was an overall increase of 35% improvement for grain yield by the demonstrated varieties of foxtail millet in farmers' field with an average productivity of 2271 kg/ha under FLDs over 1678 kg/ha in farmers practice from 2012-13 to 2016-17 as shown in the following figure.

This is mainly due to the demonstration of improved varieties like SiA 3088, SiA-3085, SiA-326 (Andhra Pradesh), SiA 3088, SiA-3085, HMT-100-1 (Karnataka), TNAU 43, TNAU-186, TNAU 196, CO 4 (Tamilnadu) in FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states.



9 Little millet production technologies and their impact

Little millet

(*Panicum sumatrense* L.)

Common name: Kutki

Vernacular names: Little millet (English), Sawai, Samalu and Same

Family: Gramineae

It is an annual herbaceous plant, which grows straight or with folded blades to a height of 30 cm to 1 m. The leaves are linear, with the sometimes hairy laminae and membranous hairy ligules. The panicles are from 4 to 15 cm in length with 2 to 3.5 mm long awn. The grain is round and smooth, 1.8 to 1.9 mm long. It is wonderful millet which is suitable for people of all age groups. It helps to prevent constipation and heals all the problems related to stomach. It improves the semen counts of men. It also helps for women with irregular periods problems. Its high fiber helps to reduce the fat depositions in the body. The little millet contains 8.7-gram protein, 75.7grams carbohydrate, 5.3 grams fat and 1.7 gram mineral in per 100 grams.

Climate

Little millet originated in south-east Asia and is now a days it is grown throughout India, particularly in Madhya Pradesh Orissa Jharkhand and Uttar Pradesh. In the temperate zones of Asia; the Caucasus, China, East Asia and also in the tropics of the continent: India, Indochina and Malaysia. It can withstand in both drought and water logging. It can be cultivated up to 2000 m above sea level.

Varieties

The list of improved and popular varieties recommended for different states are given below.

S. No.	State	Varieties
1.	Orissa	OLM- 203, OLM -208, OLM-217, BL-6, DHLM-36-3, DHLM-14-1
2.	Madhya Pradesh	JK-4, JK 8, JK 36, JK-137, BL-6, DHLM-36-3
3.	Andhra Pradesh	OLM 203, JK 8, BL-6, DHLM-36-3
4.	Tamil Nadu	Paiyur 2, TNAU 63 and CO 3,C0-4,K1, OLM -203, OLM -20, BL-6, DHLM-36-3, DHLM-14-1
5.	Chattisgarh	JK 8, BL 6, JK-137, BL-4, JK 36, DHLM-36-3
6.	Karnataka	OLM 203, JK 8, BL-6, DHLM-36-3, DHLM-14-1
7.	Gujarat	GV 2, GV 1, OLM 203, JK 8, BL-6, DHLM-36-3, DHLM-14-1
8.	Maharashtra	Phule Ekadashi, JK 8, OLM- 203, BL-6, DHLM-36-3, DHLM-14-1

Seed rate: 8 kg/ha (line sowing)

12 kg/ha (broadcasting)

Seed treatment

Seed treated with ceresan @ 3 g/kg of seed and seed inoculation with Agro bacterium radiobacter and Aspergillums awamori improve seed yield.

Sowing Time Kharif- June to July

Rabi- September to October

Season

- Odisha - Middle of June
- Tamil Nadu - June and September-October
- 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.

Method of Sowing: Broadcasting and line sowing.

Spacing: Row to row 22.5 cm, plant to plant 8-10 cm and depth 3-4 cm.

Manures and fertilisers

5-10 t/ha farm yard mannure (FYM) could be applied about a month before sowing. In addition, application of 40 kg nitrogen, 20 kg P_2O_5 and 20 kg K_2O per hectare is beneficial. The fertilizer required for different states is as follows.

States	Fertilizer recommended N, P_2O_5, K_2O (kg ha^{-1})
Andhra Pradesh	20:20:0
Bihar and Orissa	20:10:0
Tamil nadu	40:20:0
Other states	20:20:0

Bio-fertilizer: Seed inoculation with *Agrobacterium radiobacter* and *Aspergillus awamori* improves seed yield.

Water management: First irrigation at 25-30 DAS and second irrigation at 45-50 DAS.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica* (kodo), *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- cultivation and one hand weeding in line sown crop and two hand weeding in broadcost 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. Isoproturon @ 1.0 kg a.i. /ha as pre-emergence spray is also effective in weeds control.

Inter cropping

- Odisha: Little millet + black gram (2:1 row ratio)
- Madhya Pradesh: Little millet + Sesamum/soybean/pigeon pea (2:1 row ratio)
- Southern Bihar: Little millet + pigeon pea (2:1 row ratio)

Cropping sequence

South Bihar: Little millet followed by Niger

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 control.

Stem borer

Apply Phorate @15 kg/ha (10% granules) in the soil at the time of field preparation.

Termites

Using 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 with either Carbendazim or Carboxin @ 2g kg^{-1} seeds

Smut

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

Management

Seed treated with Thiram @ 2.5 g/kg of seed and soaking seeds in hot water at 55 ^{o}C for 7-12 minutes.

Harvesting time: *Kharif* season crop- September to October

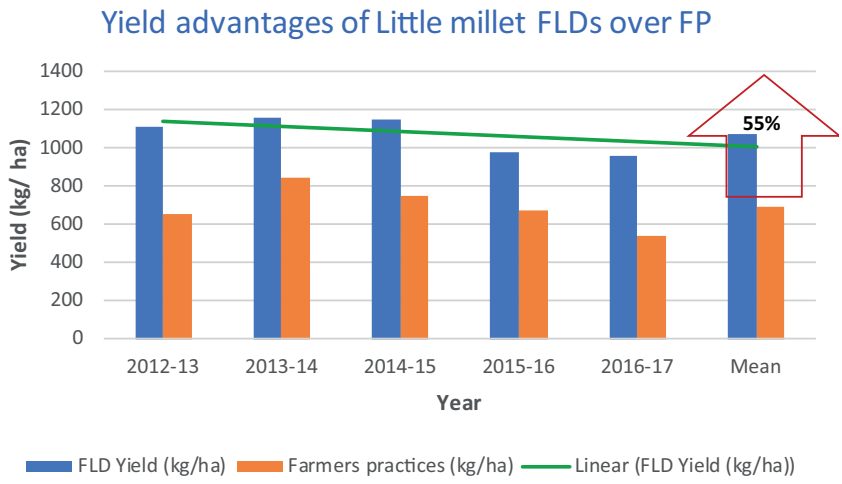
Rabi- January to February

Yield: Grain-12-15 quintal/ha and Straw-20-25 quintal/ha.

Impact of the technologies

There was an overall increase of 55% improvement for grain yield by the demonstrated varieties of little millet in farmers' field with an average productivity of 1072 kg/ha under FLDs over 694 kg/ha in farmers practice from 2012-13 to 2016-17 as shown in the figure on the next page.

This is mainly due to the demonstration of improved varieties like JK-4, JK 8, JK 36, JK-137 (Madhya Pradesh), OLM- 203, OLM -208, OLM-217 (Orissa), JK 8, BL 6, BL-4, JK 36, JK-137 (Chhattisgarh), Phule Ekadashi in Maharashtra, GV 2, GV 1 (Gujarat) under FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states.



10 Proso millet production technologies and their impact

Proso millet

(*Panicum miliaceum* L.)

Common name: Chena

Vernacular names: Proso (Common) millet (English), Cheena, Panivaragu, Variga and Baragu.

Family: Gramineae

Proso millet is an important minor millet grown in India. This crop is able to evade drought by its quick maturity. Being a short duration crop (60-90 days) with relatively low water requirement, this escapes drought period and therefore, offers better prospects for intensive cultivation in dry land areas. Under unirrigated conditions, proso millet is generally grown during *kharif* season but in areas where irrigation facilities are available, this is profitably grown as summer catch crop in high intensity rotations.

Origin and history

Proso millet probably originated in India. It spread from India to other proso millet growing parts of the world. It might have originated for *Panicum psilopodium* which is found in its wild state in Burma, India and Malaysia.

Area and distribution

Proso millet is one of the oldest grain crops and is grown in many parts of the world known by different names such as broom corn millet, hog millet,

hershey millet, proso millet or common millet, etc. It is grown extensively in India, Japan, China, Egypt, Arabia and Western Europe. In India proso millet is largely grown in Madhya Pradesh, eastern Uttar Pradesh, Bihar, Tamil Nadu, Maharashtra, Telangana, Andhra Pradesh and Karnataka.

Botanical description

It is an erect herbaceous annual which tiller profusely. Its plant grows up to a height of 45-100 cm. Stem is slender with distinctly swollen nodes. The roots are fibrous and shallow. The leaves are linear, slender and the leaf sheath encloses the entire internode. The inflorescence is a much-branched panicle without bristles having spikelets at the tips if the branches. Usually the last or the fourth glume encloses a perfect flower which sets grain. The glume and palea are firmly attached to the grain. The seeds may be creamy white, yellow, red or black.

Climate

Proso millet is known as a crop of warm climate. It is grown extensively in warm regions of the world. 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 hardly crop which completes its life cycle in a short span of time.

Soil

Proso millet can be grown both in heavy 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 *Kankar* and rise in organic matter are ideal for proso millet cultivation.

Varieties

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

S. No.	State	Varieties
1.	Tamil Nadu	Co-5, TNAU 151, TNAU 164, TNAU 145, TNAU 202, Co 4, K2, Co 3, Co 2, GPUP 21, GPUP 8 , TNPm-230
2.	Uttarakhand	PRC 1, TNAU 145, 164, 151
3.	Karnataka	GPUP 8, GPUP 21, TNAU 145, TNAU-151, TNAU-164, TNAU-202, TNPm-230, DHP-2769
4	Bihar	BR-7, TNAU 164, 145, PR 18, TNAU-202, TNPm-230
5.	Andhra Pradesh	Sagar, Nagarjuna, Co 4, Co 3, TNAU-151, TNAU-164, TNAU-202, TNPm-230
6	Uttar Pradesh	Bhawna, PRC 1, TNAU 145, 164, 151

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 the 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 after ploughing thrice followed by planking. Proso millet needs a firm and clean seedbed but does not respond to deep ploughing.

Seed and sowing

The importance of healthy and disease-free seed hardly needs to be emphasized. Proso millet is no exception. It is desirable that the seed be treated with organo-mercurial compounds like Agrosan G.N. or Ceresan at the rate of 2.5g per Kg of seed before sowing.

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 middle of April. During summer, it would be desirable to sow proso millet as soon as the harvesting of the Rabi crop is over.

Method of sowing

Proso millet can be sown by broadcasting or drilling seeds in furrows 3-4 centimetre deep.

Spacing

Row to row distance should be kept 25 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: 10 kg ha^{-1} for line sowing
15 kg ha^{-1} for 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 nitrogen, 30 kg P_2O_5 and 20 kg K_2O per hectare. Apply half of the nitrogen and whole amount of phosphorus and potash as a basal dose at the time of sowing. The remaining half of nitrogen 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 tonnes per hectare. Fertilizer required for different states is as follows.

States	Fertilizer recommended NPK (kg ha^{-1})
Andhra Pradesh	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, then 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), *Elusine indica* (kodo), *Setaria glauca* (banra), *Cynodon dactylon* (doob), *Phragmites karka* (narkul), *Cyperus rotundus* (motha), *Sorghum halepanse* (banchari)

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

Weed Control

For getting high yield and minimising loss of soil moisture and nutrients, the field should be kept weed-free up to 35 days after germination.

- Two inter cultivations and one hand weeding in line sowing
- **Pre-emergence**- Spray of Isoproturon @0.5 kg.a.i. ha^{-1} in broadcasted crop
- **Post-emergence**- Application of 2,4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS.

Cropping system

- Bihar and Uttar Pradesh: Intercropping of Proso millet + green gram in 2:1
- 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. Apply Phorate @15 kg/ha (10% granules) in the soil at the time of field preparation or Carbofuran (Furadan) 3% granules @ 30 kg/ha in furrows or as broadcast before sowing

Diseases

Head smut

- 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 per kg of seed or hot water treatment (soaking seeds in hot water at 55^0C for 7-12 minutes).

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

mature. Therefore, the crop should be harvested when about two thirds of seeds are ripe. Crop is threshed with hand or bullocks.

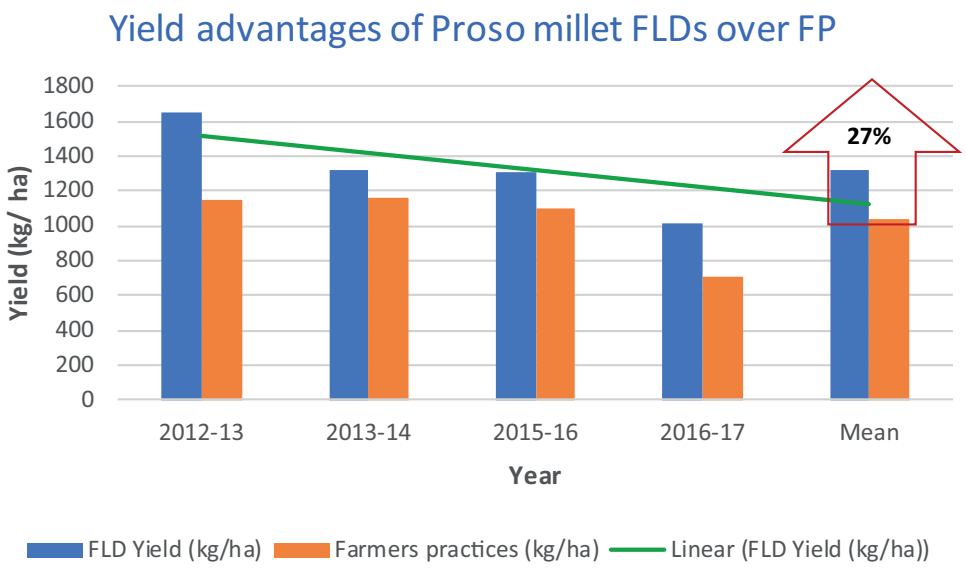
Yield

With improved package of practices it is possible to harvest 20-23 quintals of grain and 50-60 quintals of straw per hectare.

Impact of the technologies

There was an overall increase of 27% improvement for grain yield by the demonstrated varieties of Proso millet in farmers' field with an average productivity of 1322 kg/ha under FLDs over 1034 kg/ha in farmers practice form 2012-13 to 2016-17 as shown in the following figure.

This is mainly due to the demonstration of improved varieties like Co-5, TNAU 151, TNAU 164, TNAU 145, TNAU 202 (Tamilnadu), GPUP 8, GPUP 21 (Karnataka), BR-7 in Bihar in FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states.



11 Kodo millet production technologies and their impact

Kodo millet

(*Paspalum scrobiculatum* L.)

Common name: Kodo

Vernacular names: Kodo millet (English), Varagu, Haraka and Arikalu.

Family: Gramineae

Kodo millet is a highly drought resistance crop. It is the coarsest of all food grains. The kodo millet also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass originates in tropical Africa, and it is estimated to have been domesticated in India 3000 years ago. The grain is covered with a hardy seed coat which should be removed before cooking. The grain contains 8.3 per cent protein, 1.4 per cent fat, 65.6 per cent carbohydrates and 2.9 per cent ash. The grain is recommended as a substitute for rice to patients suffering from diabetes disease.

Climate

Kodo millet is grown mostly in warm and dry climate. It is highly drought tolerant and, therefore, can be grown in areas where rainfall is scanty and erratic. It is well thrive 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 preferred for satisfactory

growth. Well-drained soils with adequate moisture supply are required for uninterrupted growth of this crop.

Varieties

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

S. No	State	Varieties
1	Madhya Pradesh	JK 439, RBK 155, JK 13, JK 65 and JK 48, JK 137, RK 390-25, JK 106, GPUK 3, JK-98, DSP-9-1, TNAU-86
2	Tamil Nadu	KMV 20 (Bamban), CO 3, TNAU 86, GPUK 3, RK 390-25
3	Gujarat	GK 1 and GK 2, GPUK 3, JK-13, JK-65, RK 390-25
4	Chattisgarh	RBK 155 and JK 439, Indira Kodo-1, Indira Kodo-48, GPUK 3, JK-65, JK-98, Chhattisgarh-2, RK 390-25, TNAU-86
5	Karnataka	GPUK 3, RBK 155, RK 390-25, TNAU-86

Seed rate: 10 kg/ha (line sowing)
15 kg/ha (broadcasting)

Seed treatment: Seed treated with Ceresan @ 3 g/kg of seed

Sowing time: *Kharif*- June to July
Rabi- September to October

Season

- Sowing with onset of monsoon is beneficial.
- Middle of June to end of July in different states
- Madhya Pradesh and Chattisgarh: Last week of June to first week of July.

Method of sowing: Broadcasting and line sowing.

Spacing

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

Manures and fertilisers

Addition of organic manures is always beneficial since it helps to improve the water retention capacity of soil in addition to providing essential nutrients to the crop plants. The crop should be manure with 5-10 t/ha FYM about a month

before sowing. Apply 40 kg nitrogen, 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.

- 5-7.5 t ha^{-1} of farm yard manure
- For Tamilnadu, Madhya Pradesh and Chattisgarh: 40 kg N and 20 kg P_2O_5 ha^{-1}
- Other states: 20 kg each of NPK ha^{-1}
- High rainfall areas of Madhya Pradesh and Chattisgarh, nitrogen should be applied in 2 splits: half of the nitrogen at sowing and remaining half at 35-40 days after sowing.

Bio-fertilizers

Treating seeds with *Azospirullum brasilense* (nitrogen fixing bacterium) and *Aspergillus awamouri* (phosphate solubalizing fungus) @ 25 g kg^{-1} is beneficial. The procedure for incorporating seeds with bio-fertilizer as given for finger millet on page number 47 is followed.

Irrigation management

During dry periods, irrigations are required every 4-7 days depending on the severity of the drought and type of soil. First irrigation at 25-30 DAS and second irrigation at 40-45 DAS. Drainout the excessive rain water from the field during heavy and continuous rains.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica* (kodo), *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 at 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 twice around 20 and 35 days after sowing and 2-3 inter cultivations are necessary.
- In assured rain fall areas of Madhya Pradesh application of pre-emergence weedicide, Isoproturon @ 0.5 kg a.i./ha is also effective to control of weeds.

- Application of post-emergence weedicide 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS is effective.

Inter cropping

- Madhya Pradesh: Kodo millet + Pigeon pea (2:1 ratio)
  Kodo millet + Green gram/black gram (2:1 ratio).
  Kodo millet + Soybean (2:1 ratio).

Crop rotation / Cropping sequence

- Kodo millet – Soybean or Kodo millet or Kodo millet – Niger - Kodo millet 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 Phorate @15 kg/ha (10% granules) in the soil at the time of field preparation or Carbofuran) 3G granules @ 30 kg/ha in furrows or as broadcast before sowing.

1. Delayed sowing increases shoot fly incidence. Sowing with the onset of monsoon is beneficial.
2. Sow the crop before 2nd fortnight of July
3. Adopt higher seed rate (1 ½ times the recommended seed rate)
4. Need-based application of insecticides.

Termites and stem borer

These are two major insect pests of kodo millet. Termites may be controlled by applying Malathion 5 % Dust @ 20-25 kg per hectare or 2% methyl parathion 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.

Management

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

Head smut

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

Management

- Seed treated with Thiram or Ceresan @ 2.5 g/kg of seed and soaking seeds in hot water at 55 oC for 7-12 minutes.
- The variety GPUK 3 is tolerant to head smut

Harvesting

In *kharif* season, the crop becomes ready for harvest in the month of September or October in northern India and in *rabi* season, it is harvested from January to February.

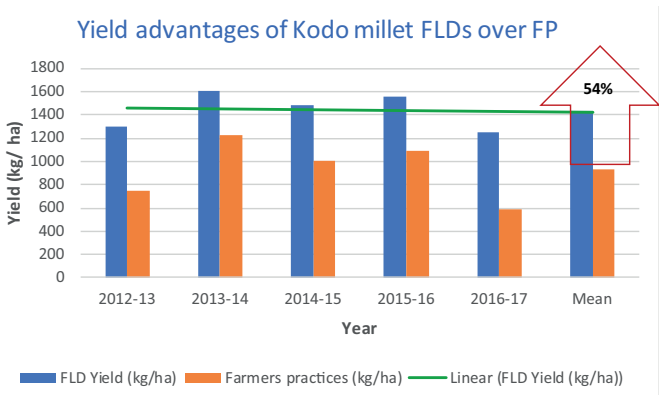
Yield

With improve package of practices, one can obtain 15-18 quintal grain and 30-40 quintal straw per hectare.

Impact of the technologies

There was an overall increase of 54% improvement for grain yield by the demonstrated varieties of Kodo millet in farmers' field with an average productivity of 1438 kg/ha under FLDs over 935 kg/ha in farmers practice from 2012-13 to 2016-17 as shown in the following.

This is mainly due to the demonstration of improved varieties like JK 439, RBK 155, JK 65, JK 48, JK 137, RK 390-25, JK 106, DSP-9-1 (Madhya Pradesh), RBK 155, JK 439, Indira Kodo-1, Chhattisgarh-2 (Chhattisgarh), KMV 20 (Bamban), CO 3, TNAU 86 (Tamilnadu), GPUK 3, RBK 155, RK 390-25, TNAU-86 (Karnataka) in Bihar in FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states.



12 Barnyard millet production technologies and their impact

Barnyard millet

(*Echinochloa frumentacea* L.)

Common name: Sawan

Vernacular names: Barnyard millet (English), Madira, Sawa, Kudraivali, oodalu and bhagar (Marathi).

Family: Gramineae

Barnyard millet is another food crop domesticated in India and grown for both grain and fodder purposes. It is quite popular in hills especially the Himalayas and important content of hill and tribal areas. It is also grown on a lesser scale in Bihar, Tamil Nadu, Maharashtra and Madhya Pradesh.

Barnyard millet is an tall erect up to 50-95 cm in height, but the stem as well as leaves are green in colour. Its leaves are flat, glabrous or slightly hairy without ligule. The grain is caryopsis and white or yellow in colour.

Varieties

The list of Improved and popular varieties recommended for different states are given on the next page.

S. No.	State	Varieties
1.	Uttarakhand	VL 172, VL 207, PRJ 1, VL 29, PRS 1, DHBM-93-3
2.	Uttar Pradesh	VL 172 and VL 207, Anurag, VL 29, DHBM-93-3, Kanchan
3.	Tamil Nadu	CO 1, CO 2, VL 181, VL 29, DHBM-93-3
4.	Karnataka	VL 172, RAU 11, VL 181, DHBM-93-3, DHB-93-2
5.	Gujarat	Gujarat Banti- 1, DHBM-93-3, VL-172
6	Bihar	VL Madira 181

Seed rate: 8-10 kg/ha for line sowing
15 kg/ha for broadcasting

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

Season

- Tamilnadu: September–October (Rainfed) and February–March (Irrigated)
- Uttaranchal and North Eastern States: April-May
- Dry seeding prior to the onset of monsoon is practiced in hills.

Sowing time: *Kharif*- June to July
Rabi- September to October

Method of sowing: Broadcasting and line sowing.

Spacing: Row to row 25 cm, plant to plant 10 cm and depth 3-4 cm.

Manures and fertilizers

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

States	Fertilizer recommended (NPK) (kg ha^{-1})
Andhra Pradesh	20:20:0
Bihar and Tamil nadu	40:20:0
Uttar Pradesh	40:20:0
Other states	20:20:0

Bio-fertilizer

Inoculating seeds with *Agrobacterium radiobacter* and *Aspergillus awamori* is recommended. The bio-fertilizers can be use as narrated on page number 47.

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 is required.

Important weeds

Grassy weeds: *Echinochloa colonum*, *Enhinochloa crusgulli* (sawan), *Dactyloctenium aegypticum* (makra), *Elusine indica* (kodo), *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 sowing
- Two hand weeding in broadcasted crop.
- Post-emergence application of 2, 4-D sodium salt (80%) @ 1.0 kg a.i./ha at 20-25 DAS.
- Isoproturon @ 1.0 kg a.i. /ha as pre-emergence spray is also effective in weeds control.

Cropping system

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

Insect-pests and their management

Shoot fly

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

Stem borer

Apply Phorate @15 kg/ha (10% granules) in the soil at the time of field preparation.

Termites

- Soil should be mixed with chlorpyriphos 5 D @ 35 kg/ha at the time of sowing. When the incidence of pest is noticed in standing crop dilute chlorpyriphos 20EC in 5 L of water and mix it with 50 kg of soil and broadcast evenly in 1 ha followed by light irrigation.
- Using Methyl parathion (2%) dust @ 20-25 kg/ha before sowing.

Diseases

Smut

The crop although affected by three different smuts, the grain smut caused by *Ustilago panici-frumentacei* is important.

Management

Seed treated with Thiram or Ceresan @ 2.5 g/kg of seed and soaking seeds in hot water at 55 oC for 7-12 minutes.

Harvesting

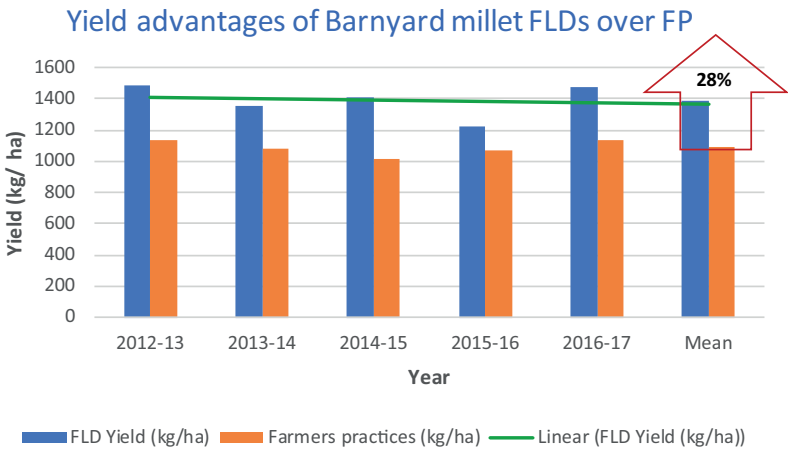
The crop should be harvested when it is ripe. It is cut from the ground level with the help of sickles and stacked in the field for about a week before threshing is done by trampling under the feet of bullocks.

Yield: Grain-12-15 quintal/ha and Straw-20-25 quintal/ha can be achieved by following the improved technologies.

Impact of the technologies

There was an overall increase of 28% improvement for grain yield by the demonstrated varieties of Barnyard millet in farmers' field with an average productivity of 1388 kg/ha in FLDs over 1087 kg/ha in farmers practice from 2012-13 to 2016-17 as shown in the following figure.

This is mainly due to the demonstration of improved varieties like VL 172, VL 207, PRJ 1, VL 29, PRS 1 (Uttarakhand), Co 1, Co 2 (Tamilnadu State), VL 172 and VL 207, Anurag, VL 29, Kanchan (Uttar Pradesh), VL 172, RAU 11, VL 181 (Karnataka) in FLDs along with latest packages of practices and further adoption of the improved technologies by farmers in various states.



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