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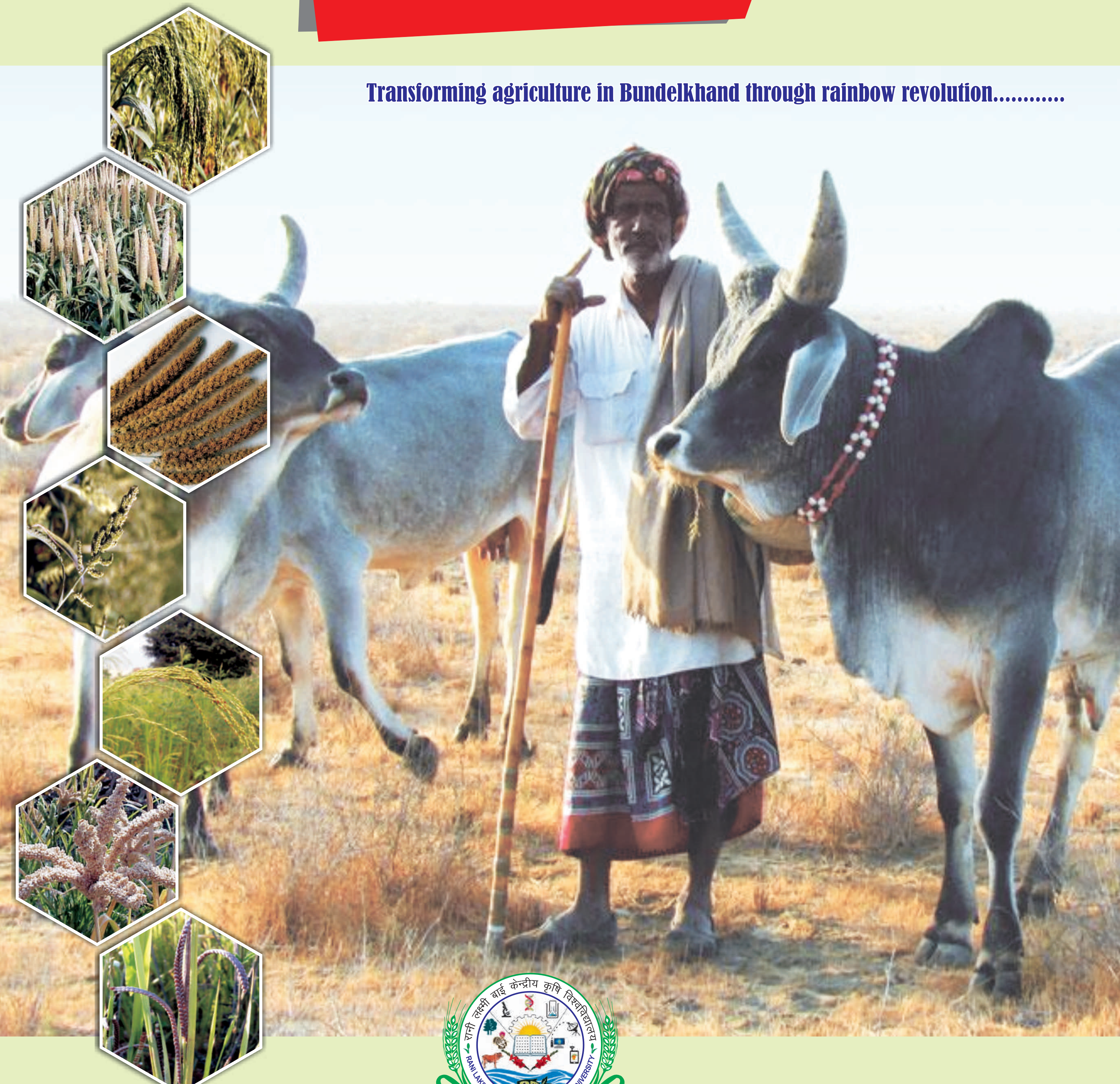
AGRI-Life

Transforming agriculture in Bundelkhand through rainbow revolution............

"Rejuvenation of Millets and Pseudocereals Production and Value Addition in Bundelkhand: Enormous Opportunities for Agri-Start-Ups and Enterprepreneurship Development"



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From Vice Chancellor's Desk...

"Millet" is a generic term for a heterogeneous group of forage grasses known for their small coarse grains. There are at least 10 genera and 14 species of millets belonging to the Poaceae family. They are important because they are grown in poor soils with limited inputs and they constitute a major source of food to the poor farmers. The most prominent and well known millets are the large or great millets of Africa, *Sorghum* and *Pennisetum*. These two taxa account for the majority of millet grain produced around the world. The rest of the millets are often referred to as the small or minor millets. Minor millets include foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), proso millet (*Panicum miliaceum*), kodo millet (*Paspalum scrobiculatum)*, barnyard millet (*Echinochloa* sp.) and finger millet (*Eleusine coracana*).

Nearly 60% of total farming in our country is covered under rainfed farming. Millets are traditionally cultivated in rainfed conditions and these are the oldest cultivated crops in India. Nearly 60 million acres of land is under millets in which 80% of Asia's production contributed by India. Millets cultivation can be a remedy for this problem as they can grow on shallow, low fertile soils with a pH of soil ranging from acidic 4.5 to basic soils with pH of 8.0. Millets are mainly grown in grown in *Kharif* season (May-June) and comes to maturity during September-October. These crops majorly grown in regions receiving less than 450 mm. About 50% of sorghum & 80% of millets production is used for human consumption whereas the rest is used for poultry feed, breweries and other industrial purposes.

Millets are grown in 21 states on 14.72 million hectares in 2016-17 from 37 million ha in 1965. This decline was due to the changes in food habits, low yield of millets and shifting of irrigated area towards rice and wheat. Even though, the farmers cultivating jowar, bajra and ragi have been highly exhibiting low productivity and profitability. The positive nutrients status and importance of millets paved way for developing a decentralized model for rejuvenating and focusing on value addition of these produce. Moreover, there is need to promote the production of millets by providing a price support mechanism to ensure the farmers not only on social dimension but also in nutritional and environmental aspect of these crops.

The new dimension for millets came up in the form of processed manufacturing produce. Several start-ups have limelighted the scope for flourishing millet in their product-mix. The sensory acceptability of millet-based products can be improved by mixing millet flours with other flours of high acceptability and preparing composite foods. The use of millets in commercial/packaged food will encourage farmers to grow millets and will open new opportunities and revitalize the farmers. This will not only serve as income for the farmers but also enhances the health standards of the community as a whole. The implementation of millet-based foods in national and state-level programs will help to overcome the existing nutrient deficiencies of protein, calcium and iron in developing countries.

It is expected that the articles published in Agri-Life will enhance the awareness towards the highly nutritious millets for wider acceptance and consumption across the country.

Lastly, I congratulate Prof Anil Kumar, and other members of editorial board for their efforts in bringing out this valuable publication. This will take a lead in promoting millet in the country, given its potential for offering nutritional security. I hope the publication will be read and used widely.

(Arvind Kumar)
Vice Chancellor

Editorial

Rejuvenation of millets and pseudocereals production for value addition in Bundelkhand: Enormous opportunities for agri-start ups and entrepreneurship development

Agriculture is the mainstay of the Bundelkhand region facing challenges of uncertain and deficit rainfall, poor soils coupled with drought and heat stress. Earlier the millets were the main agricultural crops in this region, but vanished over time due to lack of suitable varieties, low yield, marketing and other reasons. Compared to major cereals, the millet crops have the ability to withstand varied conditions of heat, drought and tropical weather. The grains can be stored for years without insect damage, which make them particularly valuable for famine-prone areas. These traditional millets provide food grain as well as quality fodder, especially in the rain-fed areas. These nutri-dense millets and pseudocereals are the reservoir of calcium and iron, and essential amino acids (lysine), which are lacking in the diets of hundreds of millions of the poor who live on starchy foods such as polished rice, and maize meal. The high nutritional value coupled with the hardiness makes them desirable climate-smart crops for food security. In the light of millets nutritional quality and tolerance to abiotic stresses, there is an urgent need to revive millet cultivation in the region. It will enable us to develop a value chain model from promotion of cultivation, production and value addition in such a manner so that not only farmers but also the consumers and processors are benefitted. These efforts shall further potentiate the development of Agri-Start-Ups through state and central government funding agencies as a part of employment generation, livelihood option and ensuring nutritional security.

Millets are traditional and staple food for most of the dry land areas of the world. In India, millets are grown on about 17 million ha with annual production of 18 million tones and contribute 10 percent to the country's food grain basket. Besides, they also form important raw material for potable alcohol and starch production in industrialized countries. Millets (great millet – sorghum, pearl millet -bajra, finger millet – ragi, foxtail millet, little millet, proso millet, barnyard millet and kodo millet) are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture and are stable yielders.

The major reasons of decrease in consumption is the lack of awareness of nutritional merits, inconveniences in food preparation, lack of processing technologies and also the government policy of disincentives towards millets and favoring of supply of fine cereals at subsidized prices. It has become imperative to reorient the efforts on the sorghum and millet crop to generate demand through value-addition of processed foods through diversification of processing technologies, nutritional evaluation and creation of awareness backed by back-ward integration. In this context it is important to explore ways for creating awareness on nutritional merits of millets.

The importance and nutritional value of millets as a foundation for healthy development is not focused as much people are very conscious on their healthy living practices to compete with various metabolic disorders and life style diseases. This magazine Agri-Life with the Theme-Millets deals with the review on the scientific and empirical studies on the pros and cons of nutritional and functional benefits of millets from seed to processed products, which are considered most important in India and across the globe.

The demand of value-added products is continuously increasing due to lack of time in this competitive era. Hence, people prefer **"Ready to eat and easy to carry food items"** for fulfilling their nutritional and food requirements. Development of a nutraceutical and market for such value- added products are envisioned to grow many-folds in the coming years. The millet products utilization by value addition and processing has immense potential in Bundelkhand for better resource utilization and nutritional security.

It is my privilege to present the third issue of "**Agri-Life**". The endeavor in this magazine is to present the recent scenario of millets and pseudocereals from various disciplines with detailed narration of its importance. It supplements in the field of scientific studies and adds to national importance.

My thanks to all the members of the editorial team, officials and employees of RLBCAU, who have participated for the successful execution of this magazine. I solicit valuable feedback from the users, the students and research communities, who will in turn, help us in further enhancing the utility of the publication.

(Anil Kumar)
Editor-in-Chief

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Barley production technology for Bundelkhand region (MP and UP)

A.S. Kharub, Dinesh Kumar, Vishnu Kumar*, R.P.S. Verma and G.P. Singh

Bundelkhand region consists of seven districts of Uttar Pradesh (Chitrakoot, Banda, Jhansi, Jalaun, Hamirpur, Mahoba and Lalitpur) and six districts of Madhya Pradesh (Chhatarpur, Tikamgarh, Damoh, Sagar, Datia and Panna) and the agro-climatic conditions of the region favours barley cultivation.

Adaptation

- Barley is a *rabi* (winter season) cereal crop having short growing season.
- The ideal condition for growing barley is moderately dry period for sowing.
- It is a hardy crop and is quite suitable for rainfed and drought prone areas and sodic condition.
- Barley can be grown successfully on a wide range of soil from sandy to heavy loam. It thrives well in drained, moderately fertile loam or light soil.
- The desired tilth may be obtained by one ploughing with cultivator followed by harrowing. The land should be planked after ploughing or harrowing as it breaks the clods.
- Now a days it has been found that it grows well in zero tillage/conservation agriculture conditions which saves energy, time and money.

Sowing Time:

- Barley is a *rabi* (winter season) cereal crop can be sown from 1st to 3rd week of November for better yield. Delayed sowing reduce the grain yield per unit area and produce poor quality grain.
- The crop requires around 12-15°C temperature during growth period and around 30°C at maturity. High temperature affects barley at various stages of growth.

Varieties

A good crop of barley could be obtained only by adapting of high yielding and disease resistant varieties as per production conditions/purpose. Huskless varieties for food purpose are recommended. Barley is recommended for Uttar Pradesh and can be grown in Bundelkhand area also. Varieties recommended for salinity in areas of NEPZ and NWPZ can also be grown in salt affected areas of Bundelkhand. Malt purpose two row barley varieties recommended for NWPZ can also be grown in Bundelkhand area.

Production condition and area adaptation

Variety	Year	Production condition	Area of adaptation	Av. yield, (q/ha)	Potential yield (q/ha)
Six Row Feed, Barley, Timely Sown, Central Zone (CZ)					
DWRB137	2018	CZ	Irrigated	42.49	67.44
RD2899	2019	CZ	Irrigated	42.19	57.43
BH 959	2015	CZ	Irrigated	51.0	65.0
RD 2786	2013	CZ	Irrigated	50.20	61.40
RD 2715	2008	CZ(Dual purpose)	Irrigated	26.30	54.50
PL751	2007	CZ	Irrigated	47.30	64.10
Six Row Feed, Barley, Timely Sown, North Eastern Plains Zones (NEPZ)					
HUB 113	2014	NEPZ	Irrigated	43.20	63.77
K 560	1997	NEPZ	Rainfed	30.40	46.40
K 603	2000	NEPZ	Rainfed	29.07	38.40
Hulless/Naked barley, Timely Sown					
Getanjali (K1149)	1991	Uttar Pradesh	Irrigated	21.31	27.81
NDB 943	2009	Uttar Pradesh	Irrigated	25.00	38.00

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Seed rate and Spacing

- The seed rate of barley depends upon its test weight, spacing, sowing time, and method.
- 100kg seed/ha is optimum for good crop yield.
- The seed of barley should be sown to a depth of 5-7 cm at a distance of 22-23 cm. Malt barley crop can be sown at a distance of 18-20cm

Seed Treatment

- To control the seed borne diseases, seed should be treated with Bavastin/Vitavax in the ratio of 1:1 @ 2 g per kg seed or treat the seed with Tebuconazole 2 DS @ 1g/ kg.
- For the control the termite, Chlorpyriphos (20EC) 125 ml per 100kg seed in 5 liters of water can be used.

Sowing Method

- Line sowing is far superior method than the broadcasting method. Seed are sown with a seed drill which ensure uniform seed placement, less – lodging, better management of weed etc.
- Happy seeder should be used for sowing in rice/ residue based field. It will save time, energy and money. This resource conservation technique enhance the nutrient and water use efficiency, soil fertility/organic carbon and reduces soil temperature, reduces weed flora and terminal heat effect.

Nutrient Management

- Fertilizer application to the barley crop is negligible and its requirement depends upon soil test report, climate and crop variety.

Recommendations of nutrient are as follows:

Zone/State	Production conditions	Recommendations N:P:K, kg/ha
Central Zone and	Irrigated timely sown	60:30:20 (feed barley)
North Eastern Plains Zone	Rainfed	40:20:20
Dual Purpose in Plains	Irrigated/ rainfed	75:30:20 (plains)

Water management

- Barley is generally grown either on conserved soil moisture from the preceding monsoon season or under restricted irrigation.
- Frequency and number of irrigation depends on the rains, soil type, variety, availability of water etc. usually barley needs 2-3 irrigation.
- First irrigation should be done at active tillering stage which comes about 30-35 days after sowing.
- Second irrigation is done at flag leaf stage, comes about 60-65 days after sowing.
- Third irrigation is done at milky stage, comes about 85-90 days after sowing.
- Of these stages active tillering and milky stage are most critical stage for irrigation.
- Heavy irrigation should be avoided as it cause lodging, severe yellowing as well as reduction of tillering.
- In case of sprinkler irrigation, first irrigation should be applied 25 days after sowing and after that every 20 days interval crop requires sprinkler irrigation.

Weed Management : Weed generally pose a greater problem in irrigated areas, though barley is a fast growing crop. One hand hoeing after first irrigation is sufficient. Following herbicides have been recommended for control of weeds.

Type of weeds	Weedicides	Dose/ha	Method of application
Broad leaf	2,4-D	500 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Metsulfuron	4 g	Spray at 30-35 days after seeding using 400-500 litres of water
Narrow leaf	Pinaxaden (Axil)	35 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Pendimethilin	1000-1500 g	Spray pre-emergence using 400-500 litres of water

Both Narrow and Broad leaf	Isoproturon	750-1000 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Isoproturon +2,4-D	750+500 g	Spray at 30-35 days after seeding using 400-500 litres of water

Harvesting

- Barley ears bend downwards when they mature and are prone to be blown off by strong winds and causes yield loss. So barley must be harvested around the moisture content of 12%.
- In malting barley, skinning of the grain is avoided during harvesting. Skinning impairs germination and introduces problems during malting.

Barley as green fodder for dry areas

- In the recent years it has been observed that because of severe drought in the drier parts of northern plains, there was an acute shortage of green fodder during the lean period (November to January). Barley can supplement as a source of green fodder in such conditions.
- The crop can be given one cut at 50-55 days after sowing for green fodder and the regenerated crop may be utilized for grain purposes. Since both the green fodder and grain can be utilized for animal fodder/ feed purposes, the crop can be advantageous over oats, because of its dual utilization as well as less water requirement.
- Barley variety RD2715 can be used as dual purpose barley in central zone. This variety can yield green fodder 200 to 250 q/ha and grain yield 25 to 30 q/ha from regenerated crop.

Challenges and issues

- High yielding malt and feed barley varieties resistance to leaf blight
- Development of high yielding hulless variety for the area for food products and consumption
- Availability of quality seed and
- Awareness of barley consumption for health benefits.

Agriculture is a fundamental source of national prosperity.

- J. J. Mapes

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If agriculture goes wrong, nothing else will have a chance to go right in the country.

- M. S. Swaminathan

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Agriculture is our wisest pursuit, because it will in the end contribute most to real wealth, good morals, and happiness.

- Thomas Jefferson

Amaranth a non-traditional alternative food crop for reviving drought hit and rainfed agriculture of Bundelkhand

Rajendra Prasad Meena, Dinesh Chandra Joshi, Hanuman Ram and Manoj Parihar

Bundelkhand is a hard rock area with inadequate ground water resources, lack of infrastructure, limited access to improved technologies, markets and inputs with low productivity. Average precipitation of this region is 800-900 mm. But, during last eight years, this area received only 400-450 mm annual or average rainfall. Early and late onset of monsoon and uneven distribution of rainfall causes serious concern of farmers for growing crops. Since last eight years this region has been facing severe drought problems. Agriculture which is mostly rainfed has been the main livelihood occupation of the farmers is facing one of the worst crises ever. However, due to acute climatic vagaries, agriculture production is continuously decreasing in this area. For instance, as in the year 2000, this region used to contribute about 15% of the states total food grain production, which has now reduced to only 7%. Due to climate change and changing precipitation pattern, a zone known for food security has now become a symbol of insecurity and migration. Incorporation of non-traditional, nutritionally unparallel and climate resilient alternative crops under water scarce, rainfed conditions of the region would be a potential strategy to revive the agriculture for livelihood security and

Introduction

Amaranth is one such *pseudocereal* crop with potentially tremendous but under-explored source of nutraceutical properties. The C4 photosynthetic pathway and ability to withstand under environmental stress make the crop a suitable choice for climate resilient agriculture in Bundelkhand region. The name amaranth in Greek signifies "immortal" which could have been derived from its hardy nature to biotic and abiotic stresses and growing habitat. The gluten free nature of the protein, low glycemic index, balanced amino acid, micro-nutrient profile and bioactive flavonoids of diverse therapeutic properties makes it a golden crop of future agricultural systems of the region. Containing the highest amount of squalene among vegetable oils, amaranth grains are increasingly becoming important for research as this biomolecule has gained the immense medicinal importance especially in skin remedies and more recently in cancer treatment. Amaranth may become an option not only for grain production, but also for a highly nutritious leafy green vegetable production under such prevalent edaphic and scarce climatic condition.

Botanical description of amaranth:

Amaranth, genus of 60–70 species of flowering plants in the family Amaranthaceae, distributed nearly worldwide. Most of these species are native to the America, and only 15 species are native to Africa, Europe and Asia. Grain amaranth has a wide adaptability and can grow in wide geographic areas ranging from tropical lowlands to 3500 m in the Himalayas. The plant is a tall, robust annual herb, simple or branched and grows up to 300 cm height. The three grain amaranth species exhibit variation for inflorescence characteristics, morphological features, plant type and can be identified by mature inflorescence alone (Fig. 1). Grain amaranth is an annual crop with a life cycle of 4–6 months from planting to harvest. Based on their uses amaranth classified in two types, grain amaranth and leafy (vegetable) amaranth. There are three grain amaranth species, viz. *A. hypochondriacus, A. cruentus* and *A. caudatus*. The leafy amaranths are tall soft natured annuals grown for their green leaves and succulents stems are cultivated throughout India. The two important vegetable species are *A. lividus* (choti chaulai) and *A. tricolor* (badi chaulai).

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A. hypochondriacus *A. caudatus* *A. cruentus*

Figure 1: Inflorescence of three grain amaranth species

Nutritional profile of grain amaranth

Grain and leaves of amaranth are an excellent source of high quality protein and lipids with higher contents of minerals, such as Ca, K and P than cereal grains (Table 1). Amaranth recorded higher nutritional value than cereals and it contains about more than three times the average amount of calcium than major cereals and is high in iron, magnesium, phosphorus and potassium. Amaranth has an excellent composition in essential amino acids and its protein quality is much higher than conventional food sources like rice, wheat, barley and maize. Most of cereal grains are usually deficient in the essential amino acid lysine and contain excess of leucine, isoleucine and valine, while amaranth is rich in lysine (5.2–6.1 g/100 g protein) and therefore has a well-balanced composition of amino acids. In the same way, sulfur-containing amino acids in amaranth (2.6–5.5 g/100 g) are comparatively higher than in most of the leguminous crops (1.4 g/100 g). By virtue of these qualities, there has been an increased interest in amaranth related to its diverse use as a nutritional substitute in food formulations, pharmaceutical use, animal feed and for commercial starch production.

Nutraceutical properties of grain amaranth:

Amaranth possesses many medicinal properties such as anti-diabetic, anti-hyperlipidemic, spermatogenic, anti-cholesterolemic effects, antioxidant and antimicrobial activity. Containing the highest amount of squalene among vegetable oils, amaranth grains are increasingly becoming important for research as this biomolecule has gained the immense medicinal importance especially in skin remedies and more recently in cancer treatment. Various other compounds of amaranth, such as saponins, tannins, phenols, flavonoids, alkaloids, cardiac glycoside, steroid and triterpenoids, have been reported to have anti-inflammatory and anticancerous effects. Historically, amaranth has been used in traditional medicines around the world for numerous purposes.

Table 1: Nutritional value of grain amaranth in comparison to major cereals

Nutrients/100 g	Amaranth	Wheat	Rice	Maize	Common bean
Protein (%)	14.5	11.8	7	9	24.8
Energy (Kcal)	374	346	345	365	322
Fat (%)	10.2	2.7	0.5	5.2	2.5
Starch (gm)	62.7	65.7	71	70.6	55.4
Dietary fiber (gm)	8.8	12.5	4.1	9.3	8.5
Calcium (mg)	162	30	41	20	143
Iron (mg)	10	3.5	3.3	1.8	5.5
Magnesium (mg)	250	108	64	127	114.3
Phosphorus (mg)	455	298	235	256	368.4
Potassium (mg)	503	284	268	287	147.8

Cultivation practices

Climatic requirements

Amaranth is grown in diverse environments ranging from the true tropics to semiarid land from sea level to high Himalayas. It is usually cultivated within 300 Latitude of the equator. Grain producing amaranth largely dominated in high land valleys, such as Himalayas. However, for the cultivation of amaranth, elevation is not much limitation. It can grow satisfactorily from sea level to above 3000 meters. For the excellent germination of amaranth seeds, ideal temperature range required from 16^0 C to 35^0 C. Amaranth also known for it is importance from its C_4 pathways and relatively low water and input requirements. Once the growth of the plant is well underway it can even withstand under acute drought stress and extremely harsh conditions.

Soil and nutrient management

Amaranth can grows well on soil containing widely varying level of soil nutrients. Various studies have been done to know impact of fertilizers on the growth of Amaranth. However for good growth of amaranth it requires good soil fertility, the soil must be rich in potassium and nitrogen content. Amaranth requires well-drained sites and appears to prefer neutral or basic soil. For taking better crop yield apply FYM @ 10 t/ha before planting. At the time of planting apply $N:P_2O_5:K_2O$ @ 50:50:50 kg/ha. Another 50 kg of N can be applied at regular intervals as top dressing. Spraying 1% urea immediately after each harvest of leafy vegetable will increase the green leaf yield of amaranth.

Selection of suitable varieties

The research progress for amaranth like area specific varietal development and development of best agronomic management practices is still in its beginning phase and need further developments to understand the complexities of adaptation to new introduced area and quality for their further utilization. All India coordinated research project on potential crops have developed following varieties for cultivation across the country (Table 2).

Table 2 : Improved varieties of amaranath with salient features.

Name of the variety	Details	Days to flowering	Days to maturity	Plant height	Yield (q/ha)
Gujarat Amaranth 1	It was developed at SDAU, SK Nagar, Gujarat by selection from local germplasm and was released in 1991.	70	135	140	15-16
Gujarat Amaranth 2	It was developed at SDAU, SK Nagar, Gujarat through mass selection in the local material collected from village Rasana, Dist. Banaskantha, Gujarat. It was released in 2000 for Gujarat state.	70	135	140	15-16
Gujarat Amaranth-3	It was developed at SDAU, SK Nagar, Gujarat. It is a pure line selection from Vasada-1-5. It was released by All India Coordinated Research Network on Underutilized Crops during 2008.	75	140	150	15-16
BGA-2 (KAPILASA)	It was developed through selection from the local cultivar at Orissa University of Agricultural and Technology, Bhubaneswar. It was released in 2005.	70	140	160	16-18
Annapurna	It was developed through selection from the germplasm line (Pauri local) collected from Uttarakhand	71	132	138	16-18
PRA 1	It was developed through pure line selection from local germplasm collection by VCSGUUHF, Ranichauri, Pauri-Gharwal	65	125	150	18-20
PRA 2	It was developed through pure line selection from local germplasm collection by VCSGUUHF, Ranichauri, Pauri-Gharwal	70	130	140	20-22
PRA 3	It was developed through pure line selection from local germplasm collection by VCSGUUHF, Ranichauri, Pauri-Gharwal	70	130	135	22-25

VL Chua 44	It was developed at ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VKPAS), Almora, Uttarakhand. It was released in 2006.	55	100	135	20-22
Durga (IC 35407)	It was developed through selection from the germplasm 'NIC 22535' at NBPGR regional station Shimla and was released in 2006.	60	110	135	22-25

Seedbed preparation

The field must be ploughed two or three times followed by leveling for good seedbed preparation. Then make shallow trenches of width 30-35 cm are made 50 cm apart. Well rotten FYM is mixed with soil in the trenches. For taking good yield, amaranth field should be free from weeds at least for the first month to reduce the yield losses.

Time of sowing and seed rate

In the north India the crop is planted in the first or second week of May or in June and in the south India from April to May. Traditionally, the seeds are broadcast but better crop stand is achieved if seedlings are planted in rows. For better plant growth, 20-30 days old seedlings are ideal for transplanting with 20 cm plant to plant distance. Sowing depth for direct sowing should be lesser than 2 cm because seed are very small in size. The spacing between rows must be 50 cm, and 20 cm between plants. The seed rate of 1-1/2 kg to 2 kg/ha is sufficient for good grain yield.

Irrigation

For getting ideal plant stand of grain amaranth crop first irrigation should be applied just after broadcasting of the seed. Germination starts 5-6 days after the first irrigation. The next irrigation should be applied after 15- 20 days and then at the interval of 10-15 days till the crop is 2.5-3.0 months old. Thereafter no irrigation is needed.

Insect management

Usually, amaranth is less affected by insect pests and diseases. So, as far as possible, avoid use of insecticides or fungicides. Some times leaf webber (*Psara basalis)* damages the crop to a great extent. It destroys the leaf and may be controlled by the spray of 0.1 percent methyl demiton or 1.5 % quinalphos.

Harvesting

In general, the crop matures in 95-100 days. In the North Indian hills, the crop is harvested from September onwards where as in South Indian hills during Aug-Sep. The top of the mature grain plants are cut with sickles while they are still in some-what green stage, collected in cloth sheets and spreaded on the threshing yard for drying. The produce is threshed and winnowed like other cereals. Grains are allowed to dry for two or three weeks before storage. By using the improved production technologies an average yield of 20-25 quintal/hectare can be achieved. For vegetable purpose, leafs harvested after 30 days of sowing can be sold in market to fetch additional income.

Value addition

Value addition is a process employed to improve the food grain quality and reducing the anti-nutrients content by transforming them into other forms such as sprouting, roasted, popped, porridges, salted ready-to-eat grains and fermented foods. Using value addition techniques, consumption and marketing of grain amaranth can be enhanced effectively. Nowadays, amaranth based bakery products such as bread, biscuits and laddu are popular in market due to greater availability of micronutrients, dietary fiber, phyto-chemicals and essential amino acid, lysine. These value added products are very popular among the people suffering from high blood cholesterol, obesity and diabetes.

Barnyard millet: A potential food and feed crop for the drought hit Bundelkhand region

Manoj Parihar, D.C. Joshi, Rajendra Prasad Meena and Hanuman Ram

Bundelkhand region comprising seven districts of Uttar Pradesh and seven districts of Madhya Pradesh is known for its geographic and cultural uniqueness in the country. Unfortunately, in the recent past, this region has been in headlines for agrarian distress and consecutive spells of severe drought, which resulted in migration, starvation deaths, malnourishment and increasing debts on farmer's further leading to suicides. In the last decade, 17 severe drought spells and one devastating flood have been faced by the region. Under such distress and severe drought condition, cultivation of high water and other input demanding cash crops is increasingly become difficult day by day. Under such circumstances farmers need to go back towards their traditional low water demanding millet crops. Till the early 1970s, many traditional types of millet like *kodo*, *kuttu*, *sawa* and *ragi* were grown in abundance in the region and used to be the constitute the integral part of diet. However, with the onset of green revolution, high yielding varieties of rice, pulses and other crops has dramatically replaced these crops. Now, after nearly four decades when entire region is facing severe water crisis, there is an urgent need to go back to traditional millets. By virtue of their efficient photosynthetic pathway and outstanding nutritional profile, millets can serve as alternative crops in the region because they can thrive well under moisture and heat stress and flourish well in marginal and low fertile ecosystems.

Introduction

Among these traditional millets, barnyard millet or *sawan* (*Echinochloa* sp.) is very important and cultivated in marginal areas where small options are available for crop diversification. Barnyard millet (*Echinochloa* sp.) is one of the oldest domesticated millets which showed parallel evolution in the semi-arid tropics of Africa and Asia. Out of 35 species under genus *Echinochloa*, two species *E. esculenta* (Japanese barnyard millet) and *E. frumentacea* (Indian barnyard millet) (Fig. 1) are mainly grown in Asia, especially in India, China and Japan. Indian barnyard millet is well adapted to both temperate and tropical environments, while Japanese species well adapted to temperate conditions of North West Himalaya. Being a hardy crop, it can be grown easily in stressful environment without compromising yield potential. Another important feature of this crop is short life span and wider adaptability, which make it suitable to cultivate under rainfed conditions. Barnyard millet has potential to provide food and nutritional security where few options are available to satisfy nutritional demands. Recently, market demand of this crop has risen due to greater nutritional value of its grain.

Figure 1: Panicles of Indian (*E. frumentacea*) and Japanese (*E. esculenta*) species of barnyard millet

Nutritional importance of barnyard millet:

Barnyard millet grains contains high protein content (11.1% to 13.9%) than major cereals like maize and rice (Fig. 2). Grains of barnyard millet contain 65% carbohydrate which is known for its slow digestion thereby lowering blood cholesterol and slow release of glucose in blood. It has been widely accepted fact that regular consumption of

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barnyard millet helps to control blood sugar level. Barnyard millet, in comparison to other small millets, contains low tannin levels (102.96 mg) which further enhances its nutritional potential. Additionally, the gluten free nature of protein makes it suitable for the people who are allergic to other cereal crops. The high iron concentration of grains makes barnyard millet a super food suitable for infants and pregnant women. By virtue of this unparallel nutritional profile, many functional food products of barnyard millet (porridge, biscuits, sweets, noodles, rusk, ready mix, popped products) are available in the market along with traditional recipes such as *idli*, *dosa* and *chakli*.

Barnyard millet as climate-resilient future crop needed new and improved variety which provide higher grain and fodder yield. Most of the barnyard millet-growing areas still use local and low yielding varieties. Therefore, to fill the production gap, modern agronomic practices and improved varieties are very much needed in near future to address the food and nutritional demands of burgeoning population. The different varieties of barnyard millet are developed and released to meet the specific need of various regions. The lists of improved and popular varieties for various states are given in Table 1.

Table 1 : Barnyard varieties relesed for different states

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

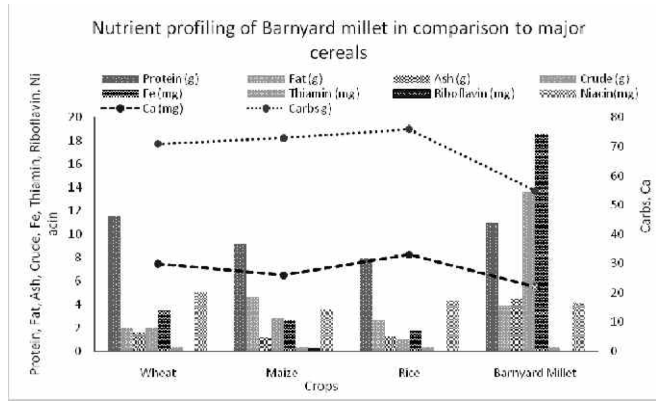

Figure 2: Nutritional profile of barnyard millet in comparison to three major cereals (source FAO 1995)

Plant habit:

Barnyard millet is an erect and tall type plant which attains 50-95 cm height and leaves are hairy without ligule. Its grains are caryopsis type, white or yellow in colour.

Soil and climate

Barnyard millet is cultivated in light texture shallow soil with low moisture holding capacity. This crop has wide range of adaptability and can be cultivated up to 2700 m above sea level with 200-400 mm rainfall. Barnyard millet grows well in tropical condition but also adapts under temperate climate. It is cultivated throughout the country, especially in Uttarakhand, Andhra Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Tamil Nadu.

Spacing and seed rate

The ideal seed rate for line sowing is 8-10 kg ha^{-1} while for broadcasting, it is 12-15 kg ha^{-1}. Appropriate spacing is 25 cm between row and 10.0 cm between plants within row.

Manures and fertilizers

Generally, 5 t ha^{-1} manure application is recommended before one month of sowing. The recommended doses of fertilizers are 40 kg ha^{-1} nitrogen, 20 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O. In addition to this, to obtain higher yield, seeds can be inoculated with bio fertilizers. Seed inoculations with *Aspergillus awamori* is recommended and give better results.

Irrigation management

Barnyard millet is a hardy nature crop and does not require irrigation, however, under drought condition, one irrigation at 25-30 DAS and another at panicle initiation stage at 45-50 DAS is recommended.

Weed management

The major weeds in barnyard millet fields are grassy type such as *Echinochloa colonum, Enhinochloa crusgulli, Elusine indica, Cynadon dactylon* etc. and broad leave type *i.e. Celosia argentia, Solanum nigrum, Amaranthus viridis* etc. For effective weed control, two inter cultivation along with one hand weeding in line sowing and two hand weeding in broadcasting method are recommended. The application of post emergent weedicide *i.e.* 2, 4-D sodium salt @ 1.0 kg a.i. ha^{-1} and Isoproturon @ 1.0 kg a.i. ha^{-1} as pre-emergence is also found effective.

Diseases and pests management

The major disease of barnyard millet crop is grain smut caused by *Ustilago panici-frumentacei* (Fig. 4). For management of grain smut, seed treatment with Thiram @2.5g/kg of seed and seed soaking in hot water is found effective.

The important pests of barnyard millet crop are shoot fly, stem borer and termites. Shoot fly causes heavy yield loss and early sowing is effective way to control it. Stem borer can be managed by mixing phorate @ 15 kg/ha during field preparation. For the control of termites, chlorpyriphos 5D @35 kg/ha in soil or methyl parathion dust @20-25 kg ha^{-1} during land preparation and before sowing is recommended.

Figure 3: Major diseases and pests of barnyard millet

Harvesting and yield

When crop is at ripening stage, stem should be cut close to the ground level using sickles and leave it in the field for a week before threshing. After completing the drying process, plants should be heaped and threshed. The average grain and straw yield of barnyard millet crop is 12-15 and 20-25 q ha^{-1}, respectively.

Post-harvest processing and value addition

Post-harvest processing of barnyard millet grains is necessary in order to make it suitable for human consumption. The traditional method of manual dehulling is drudgery prone and very difficult to perform. To overcome this difficulty, Vivek Millet Thresher developed at ICAR-VPKAS, Almora, which can process 40–60 kg grains per hour and found suitable for marginal farmers in tribal areas.

Despite nutritional superiority, overall usage and acceptability of barnyard millet is very limited which may be possibly due to non-availability of ready to use product in market and lack of commercialization. Therefore, it requires large scale production and local industry involvement with proper branding and marketing techniques to commercialize this wonder-food.

Sorghum: A potential crop for central India

Rumana Khan and Vishnu Kumar

Sorghum [*Sorghum bicolor* (L.) Moench] is an indigenous crop to Africa and though commercial needs and uses may change over time, sorghum will remain a basic staple food for many rural communities. Sorghum is one of the most important dual purpose crop grown in semi arid tropics, including India, Africa, parts of China, the southern and central Great Plains of United States, Australia, Argentina, regions of Mexico and Central and South America. Sorghum is mainly cultivated in drier areas, especially on shallow and heavy clay soils. The major sorghum growing states in India are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan, Tamil Nadu, Uttar Pradesh and Gujarat. In India, it covers about 5.82 M ha with an annual grain production of 5.39 M tonnes and productivity of 926 kg ha^{-1}. The crop is best suited to abiotic stress conditions. It is best fodder crop for ruminants due to its quick growth, tillering ability, high dry matter content, leafiness, high palatability, hardiness and suitability for silage making.

The ability of sorghum to grow in drier environments is due to a number of *physiological* and *morphological* characteristics-

- An exceptionally well developed and finely branched root system, which is very efficient in the absorption of water
- It has a small leaf area per plant, which limits transpiration
- The leaves fold up more efficiently during warm, dry conditions than that of maize
- It has an effective transpiration ratio of 1:310, as the plant uses only 310 parts of water to produce one part of dry matter, compared to a ratio of 1:400 for maize
- The epidermis of the leaf is corky and covered with a waxy layer, which protects the plant form desiccation
- The stomata close rapidly to limit water loss
- During dry periods, sorghum has the ability to remain in a virtually dormant stage and resume growth as soon as conditions become favorable. Even though the main stem can die, side shoots can develop and form seed when the water supply improves
- Competes favorably with most weeds.

Sorghum cultivation techniques-

***Kharif* sorghum**:

Seed-bed preparation: Sorghum requires a well prepared seed bed for good crop establishment. Proper tillage reduces weeds by killing the germinating seedlings and burying deep the weed seeds. Seed bed preparation is governed by local conditions such as weed intensity, moisture availability and soil erosion risks.

Planting time: Sowing of sorghum should be undertaken with the onset of monsoon. Dry sowing about one week in advance of monsoon (firm forecast) is also practiced in black cotton soils.

Varietals recommendation:

Hybrids: Early maturing: CSH23, Medium duration : CSH16, CSH18, CSH21, CSH27 and CSH28

Varieties: CSV 17, CSV 20, CSV 27, CSV 33MF

Seed rate, spacing and plant density: The optimum plant population depends upon the available moisture, soil fertility status and morphology of genotypes being cultivated. The optimum plant population recommended is 1,80,000 plants/ha. This can be achieved by using 8 kg seed and planting at 45 cm x 12.5 cm or 60 cm X 9.5 cm.

Fertilizer management: Application of 10 tons/ha FYM at the last ploughing and 40 kg N /ha fertilizer is recommended. In the absence of FYM, 80 kg of N and 40 kg P_2O_5/hectare is recommended. One half *i.e.* 40 kg N and full P_2O_5 is to be applied at sowing, while remaining 40 kg N is to be applied 30-40 days after sowing. In case of light soils with low rainfall, 60kg N and 30 kg P_2O_5 are recommended.

Weed management: Summer ploughing for destroying stubbles and perennial weeds. Timely sowing of crop should be done to minimize crop weed competition. Proper spacing to facilitate inter weeding operation. Keep the field free from weeds.

Inter cultivation: Two weeding with one shallow hoeing up to 3 weeks after sowing will keep the field free from weeds. To check severe weed infestation apply Atrazine @ 0.5 kg a.i. per ha followed by hand weeding within three weeks of sowing.

Harvesting: Ideally *Kharif* sorghum should be harvested at its physiological maturity to avoid grain mold damage.

Storage: Solarized grain by spreading on black polythene sheet. Cover it with white polythene sheet. Keep it in the sun for four hours. Remove the grain and store it in metal bins. Longevity will be at least for six months.

Sorghum - based Cropping systems

Intercropping: Sorghum intercropped with pigeon pea, sunflower, green gram or soybean has been found to be widely adopted by the farmers. The most ideal sorghum genotypes found suitable for intercropping are CSH 16, CSH 17 and CSH 18. Sorghum and pigeon pea are to be sown in the 2:1 row ratio keeping full normal population of sorghum. No additional fertilizers are required. In case of intercropping, spraying of weedicide/herbicide is not recommended. In some cases, the medium maturing sorghum genotypes such as CSH 16 and CSH 18 are also recommended for intercropping in 3:3 ratio. Another profitable intercropping system is sorghum and fodder cowpea in 2:2 row proportions. This system besides providing green fodder was also found improving soil fertility and in checking weed growth.

Sequence cropping: A sequence crop in rabi following sorghum in *kharif* was found to be profitable in those areas which receive rainfall above 700 mm and having moisture retentive medium to deep black soils. The most suitable and profitable crops are chick pea, safflower and mustard in most of the situations. The following techniques are suggested to make sequence cropping system economical and feasible.

- *Kharif* sorghum crop should be harvested at its physiological maturity to gain about one week time in planting the winter crop.
- Practice of minimum tillage needs to be adopted. It helps to gain time, minimizes land preparatory costs and prevents soil moisture loss.
- Sowing of winter crop should be drilled without much opening of the soil.
- Inter cultivation should be done at appropriate time to minimize weeds and soil water loss.

***Rabi* season**

Varietal recommendation

Varieties: CSV 14R, CSV 216R (Phule Yashoda), CSV 18 (SPV 1595), M 35-1, CSV 26, CSV 29R. **Hybrids** CSH 15R, CSH 19R

Planting time: Planting time in *rabi* sorghum is dictated by (a) rainfall pattern in the monsoon season and moisture content of the soil at the time of planting, and (b) intensity of seedling pest, the "shoot fly". Timely planting is of paramount importance in *rabi*. Planting too early invites very heavy infestation of shoot fly and delay in planting results in yield reduction due to moisture stress at grain development stage. Planting around the middle of September is ideal. In case of moisture availability, the planting could be extended up to first week of October.

Seed rate, spacing and plant density: In *rabi* season, under receding moisture conditions a plant population of 1,35,000 plants /hectare. However, under irrigated or assured soil moisture conditions, higher yields could be achieved with 1,80,000 plants

/ha. A row spacing of 45 or 60 cm with plant to plant distance of 15 cm is optimum. A seed rate of 8 kg/ha is sufficient.

Fertilizer management: Application of 10 tonnes/ha FYM with fertilizers improves soil health and uptake of nutrients at the last ploughing and 40 kg N and 20 kg P_2O_5 /ha fertilizer are advised. Under irrigated situation, 80 kg of N and 40 kg P_2O_5/ hectare are recommended. One half i.e 40 kg N and full P_2O_5 are to be applied at sowing, while remaining 40 kg N is to be applied 30 -40 days after sowing before irrigation.

Inter cultivation: Two weeding with one shallow hoeing up to 3 weeks after sowing will keep the field free from weeds. To check severe weed infestation, pre-emergence application of Atrazine @ 0.5 kg a.i. per ha keeps the crop weed free for about 20-25 days.

Irrigation management: Critical stages of irrigation are 30-45 days (seedling elongation stage); 60-65 days (reproductive or heading stages); 70-75 days (panicle emergence); and 90-95 (grain development stage). However, if only one irrigation is available, this should be applied just before booting (40-50 days) from flowering at 10 days interval or Dithane M 45 – 0.2% + Bavistin 0.2% twice at 10 days interval after commencement of flowering.

Fodder Sorghum

General cultural practices for forage sorghum are variable but are similar to those used for grain sorghum production in an ecogeographical region. Pattern of utilization of forage influences the choice of variety and cultivation practices.

Varietal recommendation: The available varieties are distinctly of two types- single cut and multi cut. The single cut varieties are PC 6, PC 23, MP Chari 1 & 2, HC 171 & 260, RC1 & 2 multi cut types are SSG 59-3, MFSH 3, Hara Sona, CSV 20 MF, CSV 33MF and the dual purpose types are CSV 15, PC 5, SPV 462 and hybrid CSH 13.

Insect pest management

Shoot fly and stem borer are the major insect pests of sorghum.

Shoot fly (*Atherigona soccata* (Rondani): Planting with the onset of monsoon in *Kharif* and between September end to first week of October is ideal to escape from shoot fly. Another important practice is to increase seed rate and destroy the dead heart seedlings after removal. Furrow application of Carbofuran 3G @ 2 grams per row or spray Cypermethrin 10 EC @ 0.02% coinciding with Shoot fly oviposition (7-14 days after germination) only for late sown crop.

Stem Borer *(Chilo partellus)*: Destroy thrashed sorghum earheads before the onset of monsoon; use high seed rate and thin out the infected plants after 10-12 days of sowing; apply Endosulfan 4G/ Carbonfurn 2 gm @ 8- 10 kg. per ha. in plant rows at 20^{th} and 35^{th} days after germination.

Disease management: Grain mold in *kharif* and Charcoal rot in *rabi* are the two major diseases effecting sorghum.

Grain mold: Molds occurs when flowering coincides with rainfall. The grains turn black, white or pink in color. Grow resistant cultivars. Spray ear-heads with Aurefungin 200 PPM + 0.2% Captan three times from flowering at 10 days interval or Dithane M 45 – 0.2% + Bavistin 0.2% twice at 10 days interval after commencement of flowering.

Charcoal rot: Charcoal rot is the significant *rabi* sorghum disease, which is serious in the shallow soils in dry areas of Maharashtra and Karnataka. Grow resistant cultivars; apply minimum dose of nitrogenous fertilizers with low plant density in infected soils; adopt inter-cropping rather than sole cropping; resort to moisture conservation practices like mulching with wheat straw; and soil treatment with Thiram @ 4.5 kg/ha at the time of sowing.

Pearlmillet: Agronomic production practices and products

Virendra Singh, Satybhan Singh and Richa Khanna

Bundelkhand region with its diversified agricultural assets in terms of soil, rainfall and climate has abundant crop diversity. Owing to drought tolerance characteristics to pearl millet, its cultivation in drought susceptible areas for providing food for human consumption, feed and fodder for animal and poultry, use as fuel and industrial uses are common. During drought condition, it helps in generating employment in low rainfall areas, where other alternative crops are limited and these crops are used as a contingent crop. As a secure source of income, these coarse cereals offer a better role during distress environment. The area of coarse cereals except maize has declined after inception of green revolution and the area of coarse cereals reduced from 44.35 million ha in 1965-66 to 26.42 million ha in 2011-12 *i.e.* 40 per cent.

Coarse cereals comprise maize (*Zea mays*), pearl millet (Bajra; *Pennisetum glaucum*), sorghum (Jowar; *Sorghum vulgare*), barley (Jow; *Hordeum vulgare*), oats (Jai; *Avena sativa*) and other minor millets for example Finger millet (Ragi; *Eleusine coracana*), Foxtail millet (Kauni; *Setaria italica*), Kodo millet (Arikalu; *Paspalum setaceum*), Proso millet (Cheena; *Panicum miliaceum*), Little millet (Kutki; *Panicum sumatrense*) and Barnyard millet (Sanwa; *Echinochloa esculenta*). Sorghum, pearl millet, finger millet, maize and small millets (barnyard millet, proso millet, kodo millet and foxtail millet) are also called **'nutri-cereals'**. Coarse cereals are rich in dietary energy, vitamins, several minerals (especially micronutrients such as iron and zinc), insoluble dietary and phytochemicals with antioxidant properties and small millets are also a good source of phosphorus and iron. Over the decades, rice and wheat have been the attention of research, development and extension efforts, habitually at the expense of coarse cereals. In the 1960s and '70s, when the procurement system expanded the government to soak these costs was much high. Similarly, milling and processing technologies for coarse cereals could not kept pace either and need more pointed focus.

Driven by the theme of doubling farmers' income by 2022, the Central government is working towards boosting the production of coarse cereals in Bundelkhand region. Coarse cereals require less water for irrigation, while their farm input costs are also economical compared to other crops such as wheat and paddy. The state government (UP) is also encouraging farmers to cultivate prominent coarse cereals, including maize, jowar, bajra (millets) and jau (barley). Currently, the total area under these four coarse cereals stands at almost two million hectares or 9.75 per cent out of the total 20.5 million hectares of cultivated area in U.P. Production wise, the total yield of maize, jowar, millets and barley during 2016-17 stood at 4.7 million tonnes or a little under 9 per cent of the total food grain production of 55.7 million tonnes in UP, according to the state's agricultural department data. The Central government has been actively promoting millets and declared 2018 as the **'National Year of Millets'.** It is also working to include millets in the targeted public distribution system (PDS) and has already notified millets as **'nutri-cereals'** for production, consumption and trade in the country. Recent studies have shown that consumption of coarse cereals could alleviate micronutrient deficiencies effectively for the majority of Indians. A diet that is removed from white, polished rice to include coarse cereals and wheat could help Indians tackle micronutrient deficits reasonably and cut down greenhouse gas (GHG) emissions associated with agriculture by up to 25 per cent. Studies have also claimed that about 500 million Indians suffer from deficiencies in

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protein, micronutrients such as iron and zinc, and vitamin A. Micronutrient deficiencies are worse in urban than in rural areas, especially in low-income households. Rural counterparts fared better due to diversity in their cereal consumption pattern. Researchers have recommended a selection of wheat, maize and millet on the plate rather than rice to boost protein intake.

Pearlmillet

Pearlmillet is one of the major coarse grain cereals and consider as poor men's food. It is broadly grown in Africa and Asia subsequently pre historic time. In Asia it is an important cereal crop in India, Pakistan, China and south eastern Asia. In India, it is the most important millet crop which flourishes well even under poor soils and adverse weather conditions. India is the largest producer of the pearlmillet covering about 8.75 million ha of marginal and sub-marginal lands primarily in the state of Rajasthan, Gujrat, Haryana, Uttar Pradesh and Maharashtra and it is the fifth important cereal after rice. From the quality point of view the grain of pearlmillet is superior in nutritive value than sorghum grains but inferior in feeding value. Bajra grains contain high protein (10.5 to 14.5%), fat (4 to 8%), carbohydrates (65 to 67.5%) and about 2.3% minerals with higher level of amino acids. Pearl millet grain comprises fairly high amount of thiamine, riboflavin and niacin. Pearlmillet is primary source of dietary energy (360 k cal/kg) for rural population in drier parts of the country and fourth most important cereal pearl millet (bajra) grains are eaten cooked like rice or 'chapatis' are prepared from bajra flour like flour of maize or sorghum. Pearl millet grain is also used as feed for poultry and green or dry fodder (karbi) for cattle. Pearl millet, being a C_4 plant, has a very high photosynthetic efficacy and dry matter production capacity. Pearlmillet is a warm weather coarse cereal grown in semi-arid and arid climate of tropical and sub-tropical regions. Pearlmillet plant does not resist the drought but cuts short its life cycle and comes to flowering early under such as adverse conditions.

High yielding hybrids, varieties and open pollinated varieties (OPVs) have been extensively accepted by Indian farmers. At present, nearly 65 per cent of pearl millet area is under improved cultivars, mainly hybrids. Following the adoption of high yielding varieties and disease resistant cultivars, pearl millet productivity has gone up from 539 kg/ha during 1986- 90 to 1009 kg/ha during 2007-11 registering 73 per cent improvement, which is highest among all food crops.

Climatic requirement

Pearl millet is a rapid-growing and warm weather crop suitable for areas with 40 to 75 cm of annual rainfall. During the vegetative growth of the crop, moist weather is useful. The rainfall at flowering time is harmful as it washes off pollen and consequently there is poor seed setting. The crop does best under environments of light showers followed by bright sunshine. Generally, pearl millet is grown in those areas where it is not possible to grow sorghum because of high temperatures and low rainfall. Pearl millet is grown as a *Kharif* crop in northern India but with irrigation it can be grown as a summer crop in Tamil Nadu, Karnataka and Punjab. The best temperature for the growth of bajra is between 20 to 28 ^{o}C. Its cultivation largely in rainfed production systems, pearl millet growth is constrained several abiotic stress. Drought is the primary abiotic constraint and is caused by low and erratic distribution of rainfall. The coefficient of variation of annual rainfall ranges from 20 to 30% leading to variable drought conditions within and between crop seasons. Hence, development of pearl millet cultivars suitable for rain fed and unpredictable low-rainfall situations has been priority area in crop improvement.

Recommended package of practices

Time of sowing

Kharif: Last week of June to 1st week of July.

Summer: Up to second fortnight of February.

Seed rate: 4 $kgha^{-1}$

Row to row distance (cm): 45 cm

Plant to plant distance: 10-15 cm

Ideal plant population/ha: 2.25 Lakhs

Bio-fertilizer): Seed treatment with Azospirrilum @ 01 packet/acre and PSB @ 01 packetacre^{-1}.

Fertilizer doses (kgha^{-1})

Kharif:N :P: K(kg ha^{-1})- Rainfed- 80:40:0

Micro-nutrient: 10 kg ha^{-1}$ZnSO_4$ or spray 2% $ZnSO_4$ in zinc deficit soils

Manures (FYM)- 5.0 Ton/ha

Weed Control

Major weeds- Amaranthus (viridus and spinosis), *Cyperus rotandus, Cenchrus biflorus, Tribulis* spp. *Digera arvensis, Celotia argensis, Euphorbia* spp.

Control Measures- Manual hoeing/weeding at 20 and 40 days after sowing

Weedicides and doses (Lit/Kg)- Atrazine : 0.5-1.0 kg ha^{-1}; 2-4 D @ 0.5-0.75 kg ha^{-1}, Atrazine: pre emergence; 2-4 D: post emergence (30-35 DAS)

Recommended production technology

- Use improved varieties recommended for the state.
- Apply N:P_2O_5:K @ 80:40:30 kg ha^{-1}. Whole amount of P & K and half of N should be drilled below seed at the time of sowing & remaining N should be top dressed 3-4 weeks after sowing coinciding with rains.
- Use bio fertilizers to improve nutrient use efficiency and increase availability of N and P.
- Rogue diseased seedling, if any. Thin and transplant healthy seedlings in gaps.
- Keep field weed free for the first 30 days either with weeding and hoeing or application of Atrazine @ 0.5 kg *a.i.*/ha as pre-emergence spray followed by one weeding and hoeing at 4-6 weeks.
- Give protective irrigation, particularly at flag leaf and grain formation stages.
- Spray Atrazine (100 ppm) or Kaoline (6%) at 15 days interval if drought occurs between flag leaf and grain formation stages.
- Use more than one hybrid/improved varieties in the same year or rotate hybrids/improved varieties in alternate years to check the spread of downy mildew.
- Use Apron 35 SD @ 2 g *a.i.*/kg of seed followed by Ridomil 25 WP (1000 ppm) spray 20 days later to check downy mildew disease occurrence and to eliminate soil inoculum.
- Follow 2:1 pearl millet + cowpea/moongbean intercropping system.

Major diseases of pearl millet:

1. Downy mildew : *Sclerospora graminicola* (Sacc.) Schroet.
2. Smut : *Moesziomyces penicillariae* (Bref.) Vanky.
3. Rust : *Puccinia substriata* var. *penicillariae*. (Zimm.)
4. Ergot : *Claviceps fusiformis* (Loveless)
5. Blast : *Pyricularia grisea* (Cooke) Sacc [telemorph: *Magnaportha grisea* (Herbert) Barr.]

Downy mildew

Downy mildew is widely distributed in all the pearl millet growing area in the world. Systemic signs as chlorosis usually appear on the second leaf and all the succeeding leaves and panicles of infected plant show symptoms. Leaf symptoms begin as chlorosis at the base of the leaf lamina and continuously higher leaves show a development of greater leaf area coverage by the symptoms. Infected chlorotic area produce massive amount of asexual spores, generally on the lower surface giving the leaf a 'downy' appearance.

Systemically infected plants remain short either do not produce panicle or produce malformed panicles. Affected plants 'green ear' symptoms appear on the panicles due to the transformation of floral parts into leafy structure that may be total or partial and such plants do not produce seed or produce very few seeds. The infested leaves produce sexual spores (oospores) in the necrotic leaf tissue late in the season.

Presently in India about 50% of the 9 million ha under pearl millet cultivation is grown with more than 70 hybrids in which DM incidence has been highly variable, with some hybrids display more than 90% incidence at farmer's field. This disease can adopt alarming levels when a single genetically uniform pearl millet cultivar is repeatedly and extensively grown in a region. Yield losses within the region can reach 30-40%.

Rust

Rust symptoms first appear on lower leaves as typical pustules containing reddish brown powder (uredospores). Later, dark brown teliospores are produced. 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 has normally been considered as a relatively less important disease in most of the pearl millet growing areas than downy mildew, ergot and smut because of its appearance, generally after the grain-filling stage, causing little or no loss in grain yield. Worldwide this disease is probably of greater importance to multi cut forage hybrids where even low rust severities can result in substantial losses of digestible dry matter yield.

Smut

Smut disease is of greater importance in India especially with the adaptation of hybrids. The disease is more severe in CMS-based single-cross hybrids than in open-pollinated varieties. The infested 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 estimated grain yield loss due to smut is 5-20%. The disease occurs during the month of September/October. Early sown crop generally escapes the smut infection.

Ergot

The disease is easily recognized as a honeydew substance of creamy to light pinkish ooze out of the infected florets which contains numerous conidia. Within two weeks these droplets dry out as hard dark black structures larger than seeds, protruding out from the florets in place of grain, which are called sclerotia. Here the loss in grain yield is directly proportional to the percentage of infection as the infected seed is fully transformed into sclerotium. The disease occurrence and spread are highly influenced by weather circumstances during the flowering time. It became more important due to cultivation of genetically uniform single-cross F1 hybrids based on cytoplasmic male-sterility system in India.

Blast

The disease is known as leaf spot of pearl millet, caused by *Pyricularia grisea* (Cooke) Sacc. [telemorph: Magnaportha grisea (Herbert) Barr.] has become a serious disease during the past few years. The disease affects both quality and production of forage and grain. The symptoms appear as distinct large, indefinite, water soaked, spindle shaped, grey centred and purple grey horizon with yellow margin, resulting in extensive chlorosis and premature drying of young leaves.

Managing pearl millet diseases

Downy mildew

- 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.)
- Seed treatment with Chitosan 10g/kg seed.
- Foliar spray of Ridomil 25 WP (100 ppm) after 21 days of sowing if infection exceeds 2-5%.
- Rogue out infected plants and bury or burn.
- Seed treatment with Ridomil MZ-72 @ 8g/kg seed and a foliar spray of Ridomil MZ-72 2g/l.

Rust

- Use of resistant hybrids/cultivars.
- Sow the crop with the onset of monsoon.
- Destruction of collateral hosts like *Ischaemum pretosum* and *Panicum maximum* on the field bunds.
- Dusting of fine sulphur @ 17kg/ha and two sprays of 0.2% Mancozeb at 15 days intervals.

Smut

- Use of resistant cultivars.
- Spray with Captafol (2ppm) followed by Zineb (2ppm) on panicle at boot leaf stage which reduces infection.
- Remove smutted ear from the field.

Ergot

- 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 sclerotia is buried deep in to the soil.
- Three foliar application of Thiram 0.2% or Copper Oxychloride 0.25% or Ziram @ 0.2% starting from 50% flowering

Major insect pest of pearl millet crop

There are many important pests of pearl millet causing losses from 10-80%. Infestation by shoot fly, white grub, stem borer, *Helicoverpa* and grass hopper is main constrain in pearl millet growing area. Similarly, root bug is a sporadic pest causing heavy economic loss in the field during epidemic. Grey weevil and leaf roller damage is also increasing as compared to previous years.

Control measures

Shoot fly and stem borer: Seed treatment with Imidacloprid 600 FS @ 8.75 ml/kg seed followed by dusting of Fenvelerate 0.4% @ 20 kg/ha or spraying of NSKE 5% at 35 days after germination was effective for the management of shoot fly and stem borer in pearl millet.

White grub: Application of carbofuran 3% or quinalphos 5% granules @ 12 kg/ha at the time of sowing is recommended. Seed treatment with Clothianidin 50 WDG @ 7.5 g/ kg seed or Imidacloprid 600 FS @ 8.75 ml/kg seed found effective against white grub in pearl millet.

Grass hopper, grey weevil and chafer beetle: Dusting of quinalphos 1.5% or methyl parathion 2% @ 25 kg/ha at the time of pest appearance is recommended. An IPM module, seed treatment with imidacloprid 600 FS @ 8.75 ml/kg seed, fishmeal trap @ 10/ha and spraying of NSKE 5% at earhead stage showed significant results for the management of pest complex of pearl millet

Cropping Systems

1. Pearl millet – Barley
2. Pearl millet – Wheat
3. Pearl millet – Chick pea
4. Pearl millet – Field pea
5. Pearl millet – Toria – Wheat
6. Pearl millet – Wheat – Moong (Green gram)
7. Pearl millet – Wheat – Jowar (fodder)
8. Pearl millet – Wheat – Pearl millet (fodder)

Crop products

Grain processing technologies

Dehulling: Both whole grains and dehulled (decorticated) grains of pearl millet are used for preparing various types of food products. Decortications is generally to the extent of removing 12-30% of the outer grain surface. Increased decortications lead to greater loss of fibre, ash and fat as well as reduce protein, lysine, histidine and arginine. Decorticated grains improve the nutritional quality and sensory properties of various food products, but these also have cost consideration in terms of the time and investment and grain weight losses. Further, these also lead to micronutrient losses, which are more concentrated in the outer layers of the grain. Pearl millet grains can be decorticated in rice mills or other modified mills. In some villages and urban areas, pearl millet grains are decorticated with abrasive disks in mechanical dehullers.

Milling: Grains can be milled either by using a hammer mill or a roller mill. The flour produced using a hammer mill has large particle size and is not uniform; and is suitable for preparing thin and stiff porridge of rough texture and not suitable for preparing baked and steamed food products of smooth texture. A new method for improving the shelf life of pearl millet has been developed at the Central Food Technological Research Institute (CFTRI), Mysore. It involves moist heating of the grains followed by drying to about 10-12% moisture and decortications to the desired degree or pulverization. This process improves the milling characteristics of pearl millet varieties which have high proportions of floury endosperm. Flour from treated and decorticated pearl millet could be stored for about 3-4 months, during which the free fatty acid (FFA) content remained below 10%, which is the limit of perceptible deteriorative condition, oxidative rancidity also remains low, as the flours are refined.

Malting: This method includes limited germination of cereal in moist air under controlled conditions. For pearl millet, a malting procedure has been developed that involves soaking of grain in 0.1% formaldehyde solution for 6 hours, followed by aeration for 3 hours and re-steeping in fresh formaldehyde solution for 16 hours. The grains are then germinated for variable periods 12, 24, 36, 48 and 72 hours, after which the grains are dried in an oven and vegetative growth is removed by abrasive action. Malting helps in the mobilization of seed reserves and elaboration of the activity of á and ß amylase and protease. Malting reduces protein, but improves the quality of protein compared to that in the bran, so a small loss in protein in milling of the malted pearl millet is compensated by protein quality. The process outcomes in a higher protein efficacy proportion and bio-availability of minerals. As compared to the high levels of polyphenols (755 mg 100^{-1} g grains) and phytic acid (858 mg 100^{-1} g grains) in the untreated controls, malting of pearl millet grains with a 48 h germination reduced polyphenols and phytic acid by more than 40%. Malting also increases vitamins such as riboflavin, thiamin, ascorbic acid, and vitamin A. There was slight result of malting on increasing the shelf-life of flour. It has been found that steeping pearl millet grains for 16 h, followed by germination for 72 h increased in vitro starch digestibility by 97%, protein digestibility by 17%, and total sugar by 97%.

Blanching: This is one of the real processing technologies to improve the shelf life of pearl millet. Blanching is usually done by sweltering water at 98 °C in a container then submerging the grains in the boiling water (1:5 ratio of seeds to boiling water) for 30 sec and drying at 50 °C for 60 min. Blanching has been observed to be effective in the retardation of enzymatic activity and thus improve the shelf life of pearl millet flour without much altering the nutrient content. Blanching of seeds at 98 °C for 10 sec in boiling water before milling has been reported to effectively retard the development of fat acidity in meal and enhance shelf life by 25 days. Fat acidity increased about 6-fold in untreated pearl millet flour, whereas it remained almost unchanged in flour obtained from boiling water-blanched grains (98 °C for 30 sec). As compared to the high levels of polyphenols (755 mg 100^{-1} g grains) and phytic acid (858 mg 100^{-1} g grains) in the untreated controls, blanching of pearl millet seeds reduced the polyphenol and phytic acid contents by 28% and 38%, respectively. Also, fat acidity was reduced significantly in the case of blanched pearl millet flour as compared to raw flour after 28 days of storage.

Acid treatment: The dark-grey grain pearl millet is highly preferred in Maharashtra state of India. In India and most of the world, this grain color is not ideal for food purposes. Treating the decorticated seed with mild organic acids, such as acetic, fumaric, or tartaric, and also with the extracts of natural acidic material such as tamarind has been found to improve the product quality by reducing polyphenols and other anti-nutritional factors, thereby also increasing consumer acceptability. Various studies have reported that soaking of pearl millet in acidic solutions, like sour milk or tamarind pods, markedly reduced the color of the grain. Dehulled grains decolorized faster than whole grains because the acidic solution penetrates the grain at a faster rate**.** Among the various acidic solutions tried, dilute hydrochloric acid was more effective and suitable chemical treatment to remove pigments from whole grain before milling as compared to citric acid and acetic acid. Soaking grains in dilute HCl for 15 to 24 h reduces a major portion of these pigments and thus helps in the production of creamy white grains.

Soaking of pearl millet in 0.2 N HCl for 24 h reduced polyphenols by 76% and phytic acid by 82% as compared to 755 mg 100-1 g polyphenol and 858 mg 100-1 g grains of phytic acid in the untreated control. While fat acidity of the flour during 28 days of storage increased 4-fold in the untreated control, there was very marginal increase in the flour produced from the acid-treated grains. Similar patterns of changes were observed in the acid treated and control treatments with respect to free fatty acids and lipase activity. In another study, pearl millet grain samples given acid treatments for 6, 12, 18, and 24 h had in vitro protein digestibility increased by 29, 44, 56, and 59%, respectively, and the in vitro starch digestibility increased by 40, 57, 76, and 85%, respectively.

Dry heat treatment: Lipase activity is the major cause of spoilage of pearl millet meal, so its inactivation before milling improves the meal quality. The application of dry heat to meal successfully retards lipase activity and decreases lipid decomposition during storage. It has been detected that when pearl millet grains were given a dry heat treatment in a hot air oven at 100±2°C for different time periods ranging between 30 and 120 min, and then cooled to room temperature, there was about 50% increase in fat acidity, free fatty acids, and lipase activity during the 28 days of the storage of flour produced from the acid-treated grains, while there was a 4-times rise in these parameters in the flour produced from unprocessed grains. Heating grains for 120 min has been found to be most effective for maximum retardation of the lipolytic decomposition of lipids during storage. Fat acidity, free fatty acid presence, and lipase activity decrease significantly during storage of 28 days in pearl millet flour given an 18-h acid treatment and a 120 min heat treatment.

Parboiling: Parboiling is especially beneficial for soft-textured grains. Parboiled grains decorticate more efficiently in eliminating the germ and the pericarp. Parboiled-decorticated grains have somewhat lower protein digestibility than the raw grains decorticated to the same extent. In practical terms, however, this detrimental effect is negligible since most traditional food processes involve cooking of flour or decorticated grains. The parboiled grains can be used for various snack food items, especially for diabetics. Parboiled grains can also be cooked to produce rice-like products. In pearl millet, parboiling can extend the shelf life of the products such as *milri*.

Alternative food products and value-addition : Processed pearl millet grains and meals from them, are used to prepare various types of traditional and non-traditional food products which can be summarized and classified these into 9 major food categories (thick porridge, thin porridge, steam cooked products, fermented breads, unfermented breads, boiled rice-like products, alcoholic beverages, non-alcoholic beverages and snacks) and they provided the details of their preparations and the various common names in many countries. These products can be categorized under seven different types.

Traditional food products: The simplest and the most common traditional food made from pearl millet are thin porridge (gruel) thick porridge (fermented and unfermented) flat and unfermented bread such as chapatti. Flat, unleavened bread prepared from pearl millet flour enriched with soy flour has been reported to have high protein efficiency ratio, minimal thickness, puffing, and uniform color and texture. Chapati prepared from pearl millet flour produced after the grains had been bleached or acid-treated or heat-treated has been reported to have enhanced overall acceptability as compared to the chapati prepared from the fresh untreated grains. Use of processed flour, in comparison to raw flour in the product development has been found to reduce anti-nutrients and increase the digestibility.

Various types of snacks are also made from pearl millet in India. Products like laddoo, namkeen sev, and matari have been made using blanched and malted pearl millet flour. These products were highly acceptable and have shown to have longer shelf life and stored well up to 3 months. Incorporated blanched and malted pearl millet flour in various products like bhakri, suhali, khichri, churma, shakkarpala, mathari and the products were found to be organoleptically acceptable. An earlier study also indicated that the traditional products including chapatti, khichri, bhakrii, popped grain, dalia, and shakkarpala prepared from pearl millet were not only acceptable but their protein and starch digestibilities were also better.

Baked products: Pearl millet flour is not a good raw material for the baking industry, since it does not contain gluten and thus forms dough of poor consistency. For instance, cookies finished from pearl millet flour do not spread during baking, have a poor top grain character, and are thick and dense. However, pearl millet flour hydrated with water, dried, and supplemented with 0.6% raw soy lectin can produce cookies with meal characteristics equal to those made from soft wheat flour. Various types of biscuits and cakes produced using blanched pearl millet have been found to be organoleptically acceptable. Various types of biscuits developed by incorporating different levels of blanched as well as malted pearl millet flour have been found to be acceptable and store well up to 3 months.

Extruded products: Extrusion is being used increasingly for making ready-to-eat foods. In extrusion processes, cereals are cooked at high temperature for a short time. Pearl millet grit and flour can be used to prepare ready-to-eat (RTE) products. Such products have crunchy texture and can be coated with traditional ingredients to prepare sweet or savoury snacks. Alternatively, the grits could be mixed with spices and condiments prior to extrusion to obtain RTE snacks of desirable taste. The acid-treated pearl millet yields goods of better acceptability as related to that from just decorticated pearl millet. Pearl millet, blended with soy or protein-rich ingredients, such as legumes or groundnut (peanut) cake, on extrusion gives nutritionally balanced supplementary foods. Extruded pearl millet products prepared from a blend of 30% grain legume flour or 15% defatted soybean had, respectively, 14.7% and 16.0% protein, and 2.0 and 2.1 protein efficiency ratio. The shelf life of the extrudes was about 6 months in different flexible pouches under ambient storage conditions. Noodles, macaroni and pasta-like extruded products could be arranged from pearl millet flour. Extruded snacks prepared with mixed millet flour containing rice flour and/or corn flour and/or tapioca starch in various proportions have been shown to have acceptable appearance, color, texture, and flavor. Extrusion-cooking also enhances the *in vitro* protein digestibility of foods.

Utilization of pearl millet for producing soft-cooked products such as vermicelli noodles is very rare, although these grains are unique with respect to taste aroma and also provide dietary fibre. The noodles on cooking in water retained the texture of their strands and firmness without disintegration, and the solid loss is less than 6%. The noodles from pearl millet are readily acceptable in the savoury and sweet formulations.

Flakes and pops: Extensive work has been carried out on sorghum flaking at CFTRI, Mysore and various process parameters, such as soaking time, temperature, wet-heat or dry-heat treatment conditions, have been standardized (CFTRI, 1985). The grain soaked to its equilibrium moisture content is steamed or roasted to fully gelatinize the starch, dried to about 18% moisture content, conditioned, decorticated, and then flaked immediately by passing through a pair of heavy-duty rollers. The flakes can also be used for the preparation of traditional snacks like 'uppitu' after boiling and seasoning. Results of examining studies on flaking of pearl millet following the method adopted for sorghum have been promising. Pearl millet flaking would be a new avenue for its widespread utilization. Since stabilization of the oil occurs during flaking, pearl millet flakes will have longer shelf life. Since popping involves formation of steam and development of pressure inside the grain, the optimum moisture level and popping temperature play important roles in the quality of the popped cereal. Varietal differences occur largely with respect to popping features. The optimum conditions for grain popping, according to the CFTRI process, are equilibrating pearl millet to about 16% moisture and subjecting the grains to a high-temperature, short-time treatment (about 230^{o} C for a fraction of a minute) in an air popper developed at the Institute (CFTRI 1985). The machine is highly suitable for value addition to pearl millet by popping.

Popping of pearl millet is not very popular, but the popped pearl millet is a good source of energy, fiber and carbohydrates. Varieties with tough endosperm and medium-thick pericarp display superior popping quality. The lipolytic enzymes are denatured during the process of popping. The nutritional advantage of the popped millet is utilized in developing formulations for supplementary foods or weaning foods for children and mothers. Since sorghum and pearl millet are rich sources of micronutrients and phytochemicals, such products may score over similar products made from rice and wheat.

Weaning foods: Pearl millet can be successfully utilized for the development of weaning foods, as it can satisfy the nutritional requirement of infants during the crucial transitional phase of life from breast milk to other type of food, at reasonable cost. Keeping in view the delicate digestive system and nutritional requirement of the infants, malting seems to be an effective process as it provides an opportunity to develop easily digestible and nutritious weaning foods of low viscosity, low dietary bulk and of high calorie density. In addition, malting also improves the availability of protein, minerals, free sugars, vitamin B, and ascorbic acid by reducing the level of anti-nutrients and flatus producing factors. It also imparts desirable flavour and taste to the product. Blanching successfully improves the storage stability by retarding the lipolytic spoilage of meal without much altering its nutrients. Nutritive value of pearl millet based weaning foods can further be enhanced when mixed with legumes like cowpea or green gram because these pulses complement the profile of essential amino acids which is beneficial for infants' optimum growth.

Health foods: Pearl millet can find uses in preparing various types of health foods and food ingredients as it contains a relatively higher proportion of insoluble dietary fibre. This causes slow release of sugar, thus making the food products based on them especially suitable for those suffering from or prone to diabetes. For instance, various pearl millet-based food products were found to have a lower glycemic index (GI) than those based on wheat, with the extent of reduction in the GI trait ranging from 20% for biscuits to 45% for *dhokla*. Gluten intolerance, leading to protein allergy (specifically gliadin allergy), is a physiological disorder from which about 500,000 people suffer in the USA alone**.** Pearl millet is gluten-free and has a good chance of being commercialized for the food-based management of this problem. Pearl millet is rich in oil and linoleic acid accounts for 4% of the total fatty acids in this oil, giving it a higher percentage of n-3 fatty acids as compared to maize in which linoleic acid accounts for only 0.9% of the total fatty acids and is highly deficient in n-3 fatty acids. The n-3 fatty acids play an important role in many physiological functions, including platelet aggregation, cholesterol accumulation and the immune system. Pearl millet in poultry feed can have a significant effect on the fatty acid composition of eggs, consequently on human health. In a poultry feeding trial, it was observed that eggs produced from layers fed a pearl millet-based diet had lower n-6 fatty acids and higher n-3 fatty acids and leading to lower n-6: n-3 fatty acid ratios than those fed corn-based diets.

Drinks: Pearl millet flour is used in making different types of drinks. A fermented drink known as rab/rabari is consumed widely during summer months in Rajasthan. Similarly, traditional drink called as 'Cumbu Cool' is consumed in Tamil Nadu. The National Dairy Research Institute, Karnal has recently developed and launched pearl millet 'lassi' made from pearl millet flour.

Opportunities for commercialization

One of the greatest constraints in the commercialization of pearl millet grain for food purposes has been a misplaced social stigma dubbing these as poor men's crop primarily because it is grown in marginal environments, where poverty is common.

Thus, pearl millet could not make it to the food basket of the urban elite whose consumption choices play a dominant role in the commercialization of any food product. Grain quality and nutritional studies now illustration that pearl millet grains are more suitable choices for the nutritional security of the rural and urban poor who have limited admission to other sources of dietary components. In addition, pearl millet grains could also be more appropriate choice than the fine cereals such as wheat and rice for the elite who will benefit from their high nutraceutical properties. This will require different approaches to commercialize pearl millet to serve these widely different consumer classes. For instance, subsidy on wheat and rice production almost all over the world plays a big role in their production and marketing. On top of this, is the subsidized procurement and supply of wheat and rice through the Public Distribution system in India. Similar support is not available to pearl millet. This leaves farmers with little incentive for investment in production as the returns are not economical when increased production leads to a drop in grain prices. The low-resource agriculture, characterized by rain-fed cultivation of pearl millet crops with negligible external inputs, leads to low productivity with large variation in production and grain surpluses across the years. The low volume and inconsistency in grain supplies reduce the dependability of producers for grain supplies, which is so essential for commercialization. Opportunities exist to drastically reduce or even eliminate these uncertainties through governmental policy support for increased and stable production and marketing of pearl millet grain surpluses.

Most of those involved in commercial grain processing and food manufacturing are not acquainted with the possible alternate food uses and health value of pearl millet. Commercialization of pearl millet grains for alternative and health food uses needs to be viewed in a wider context from production to utilization, and developing challenges and opportunities.

The discovery of agriculture was the first big step toward a civilized life.

- Arthur Keith

The farmer works the soil, The agriculturist works the farmer.

- Eugene F. Ware

Food Barley in India: Current Status and future possibilities

Dinesh Kumar, Vishnu Kumar and A.S. Kharub

Barley (*Horedeum vulgare* L) is an ancient crop and considered as one of the earliest domesticated crops. The most probable reason for domestication of this crop is the ability to grow under diverse climatic conditions coupled with tolerance to several biotic and abiotic stresses. In India barley is grown right from higher Himalayan hills to the plains of Rajasthan. The barley crop can be grown in extremes of temperature, water availability and sick soils. Thus barley provides a sustainable cropping system component. However, with the availability of dwarf wheat varieties and assured irrigation facilities especially in the late sixties, barley got replaced with wheat and area and total production decreased drastically. Barley is then became a feed crop for animals especially in the areas where other forage crops could not be grown. Still as on date around 60% of total barley production goes for animal feed and approximately 25% for malt making and rest around 5% is directly used as the food, that too in the higher Himalyas and in some parts of Eastern India.

Its natural cycle that day comes out after every night similarly in the late nineties, the area of barley got stabilized due to opening of economy and increasing demand of malt barley started. To cater the needs of industry several high yielding malt barley varieties were developed. Malt barley is mainly being used for breweries and rest goes for energy drinks like Horlicks, Bournvita, Maltova etc. as food barley. With the changing lifestyles, increasing urbanization and vast coverage of mass media the demand for malt barley is bound to increase and thus the area and production.

In last two decades lot of research has been done on neutrceutical or health properties of barley and very positive benefits have been identified. Several health benefits of barley have been mentioned in ancient Indian scriptures. Barley and oats are two unique species among cereals having relatively higher content of polysaccharide called beta glucans. Beta glucans have been shown to decrease the cholesterol and glucose levels in the blood. Thus there is lot of scope in food barley segment and in this article a SWOT analysis has been done in this regard with respect to India.

Strengths

Barley is already being consumed as food or food products in higher Himalyas and in eastern India; therefore there is already a niche of barley acceptance as food. Multigrain atta (flour) is already has good share in the multigrain segment and barley is rather considered a healthy and sacred grain in Indian culture. As already mentioned barley is a rich source of soluble fibres especially beta glucans and has advantage as compared to oat in terms of beta glucans content and distribution in grain. Beta glucans content in barley grain can be achieved upto 7-8 % in Indian subtropical climates, while in oats it is around 5-6%. Secondly in oats beta glucans are mainly concentrated in outer layers while in barley grain it is evenly distributed especially in endosperm cell walls. Therefore even after removal of husk in barley does not lead to significant loss in grain beta glucans content, while same is not true for oats. Barley is a traditional food grain in Indian culture, while grain oats are not being grown at large scale in India. Besides beta glucans, barley is a good source of several vitamins, minerals and antioxidants. In the studies carried out at ICAR-Indian Institute of Wheat & Barley Research, it has been shown that barley grain contains higher content of antioxidants as compared to wheat. There is a strong programme on development of barley varieties and technologies in India and already several varieties are available with more than 5% beta glucans content.

Weaknesses

Barley is of different kinds like two rowed & six rowed; hulled and hull less and with coloured grains to name a few. The hulled barley is preferred by malt industry as attached husk is more suitable for making malt. For making barley based food products, removal of husk is normally required leading to loss of nutrients from outer layers, thus hull less barley grain is preferred for making barley based food products. Though hull less varieties were developed in Indian programme, but either these have lower yields as compared to hulled ones or are susceptible to one or more diseases. Further there was no targeted barley programme to develop hull less barley genotypes with superior neutraceutical properties. There is lot of

ICAR-Indian Institute of Wheat & Barley Research, Karnal – 132 001

research on health benefits of barley grown in temperate climates, but such kind of evaluation has not been carried out in case of barley being grown under sub-tropical climates. The difference in barley grain composition in terms of quantity and quality is highly expected since the barley being grown in sub-tropical climates get almost half of the grain filling period as compared to the temperate climates. Except traditional products like Sattu and Daliya, there is no availability of barley based products, thus consumer is devoid of much choice. Private industry is also focussed on oats and there is lot of advertisement of health benefits of oat products and barley has not got such attention from private sector. Except the areas where other crops are not able to grow profitably, barley is grown especially for animal feed. Growing barley with all resources may not be profitable as MSP of barley is less than wheat and secondly the total yields of barley is relatively low as compared to wheat, thus most of the farmers prefer to grow wheat or other crops like mustard due to better economic returns.

Opportunities

India is becoming the diabetes capital of world with lot of people suffering from diabetes. The incidences of cardio vascular diseases are also on rise. Both of these diseases are life style related besides the genetic component. Therefore there is an urgent need to modify our food habits to include components of nutraceutical properties. India is a growing economy at fast rate with increasing urbanization and changing lifestyles, thus there is an ample scope of barley based products in India. Slowly and slowly people are becoming health conscious and prefer foods with health benefitting properties, provided they are provided with a vast choice of barley based food products. India has a strong barley breeding and associated technology programme and has the capability of developing hull less high yielding, disease tolerant genotypes with better nutraceutical properties. There is a vast opportunity in food segment as India has much more diversity in food product consumption as compared other parts of the world. There are several different geographical regions in India which can provide suitable grain with desirable properties catering to the needs of different food habits and development of different kinds of food products. Already efforts are on for development of hull less barley varieties with higher grain beta glucans, protein coupled with higher iron and zinc content. The development of various food products like barley based chapattis, biscuits, bread, noodles, pasta are being worked upon. There is scope of developing ready to serve Sattu in different flavours. In the studies carried out at ICAR-Indian Institute of Wheat & Barley research it has been shown that in making chapattis and biscuits up to 30% barley can be incorporated without any significant effect on the quality but leading to increased beta glucans content in the final products. Similarly studies on malt barley to development of superior wheat bread in terms of quality are being done. Similarly barley based non-alcoholic beer has also made entry in the Indian market. Barley has lower glycemic index as compared to wheat thus making it a better alternative to traditional wheat chapattis. Chapatis are normally consumed as staple food in north India, if multigrain concept with barley is introduced the incidences of type II diabetes and cardiovascular diseases can be better controlled.

In the changing climatic conditions, barley having relatively better abiotic stress tolerance has better scope of adaptability as compared to other winter cereals. Barley also requires lesser resources as compared to wheat and thus can become a viable option to farmers in case whole value chain is strengthened.

Threats

As already mentioned MSP of barley being lower than wheat, the barley area cannot be expanded until/ unless industry does the contract farming with assured income of farmers. The import duty on barley grain is not there, thus the imported barley being grown in temperate climates has better quality is being preferred by the industry over Indian barley. Oat is the biggest competition of barley having already made in roads in the Indian food market, while such kind of support barley has not got. Availability of hull less barley varieties with lodging resistance and equivalent yield to wheat is a challenge for researchers to develop.

Following research and development steps may help in strengthening food barley in India:

1. Development of hull less barley genotypes with higher yield, disease resistance and superior quality.
2. Incorporation of traits of higher grain beta glucans content coupled with amylose content to decrease the glycemic index of barley.
3. Health benefitting properties are needed to be established / validated for barley grain being grown in sub-tropical climates.
4. Barley based food products need to be developed and extensive advertisement is required for awareness among consumer's fir health benefits of consuming barley based products.
5. Public private partnership is need of the hour at this front.
6. Policy decisions are also desired with respect to minimum support price of barley and import duty on barley for better remuneration to the farmers growing barley.

Improved technologies for small millets cultivation

Salej Sood

Summary : Small millets have been instrumental in imparting food and nutritional security to the people living in hilly areas from ancient time. These are short duration, warm season crops, suitable for contingent crop planning also. They possess unusual characters for adaptation like tolerance to drought, high temperature, low soil fertility and diseases as well as pests and used for making ethnic foods and beverages. In addition, they are nutritionally superior to major cereal grains. Owing to their special characteristics, they are important component of sustainable farming systems in the hilly tribal areas. Machines for post harvest processing and value added products have been developed for small and marginal farmers and the efforts are continuing in this direction.

Millets refer to any of the small seeded cereals and forage grasses, which are used for food, feed or forage. These are also generally referred as coarse cereals. In India, many kinds of millets are grown, which include sorghum, pearl millet, finger millet, foxtail millet, little millet, barnyard millet, proso millet and kodo millet. Sorghum and pearl millet are considered as coarse millets; and have considerable area, whereas the others group known as small millets or minor millets occupy mainly area. Small millets or minor millets are traditionally cultivated, important and most suited crops for rainfed agriculture (Table 1). Apart from being staple food, small millets also play an important role in providing fodder to cattle.

Table 1. Cultivation of different kind of small millets in India

Name (Vernacular name)	Botanical name	States in which cultivated
Finger millet (Mandua, Ragi)	*Eleusine coracana*	Karnataka, Tamil Nadu, Uttarakhand, Andhra Pradesh, Orissa, Maharashtra, Gujarat
Kodo millet (Kodo)	*Paspalum scrobiculatum*	Madhya Pradesh, Chhattisgarh
Foxtail millet (Kauni, Kangni)	*Setaria italica*	Karnataka, Tamil Nadu, Andhra Pradesh
Proso millet (Cheena)	*Panicum miliaceum*	Bihar, Andhra Pradesh
Little millet (Kutki)	*Panicum sumaterense*	Orissa, Bihar, Madhya Pradesh, Chattisgarh, Tamil Nadu, Gujarat
Barnyard millet (Madira, Sawan, Jhingora)	*Echinochloa frumentacea, Echinochloa esculenta*	Uttarakhand, Tamil Nadu, Maharashtra

Finger and barnyard millet cultivation

Finger millet (*Eleusine coracana* L. Gaertn) is highly self-fertilized annual plant widely grown as small grain cereal in arid and semi-arid areas of India. The crop serves as a subsistence and food security crop that is especially important for its nutritive and cultural value. The grain of finger millet has a fine aroma when cooked or roasted and is known to have many health-promoting qualities. Although grown under dry lands, it provides an assured harvest, thus making it indispensable in specific ecosystems.

Barnyard millet (*Echinochloa* spp.) is one of the oldest domesticated millets in the semi-arid tropics of Asia and Africa. In India, barnyard millet is grown from Himalayan region in the north to

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Deccan plateu in the south and in some pockets in Sikkim in North Eastern India. It is generally cultivated in hill slopes and undulating fields of hilly, tribal or backward areas, where few options exist for crop diversification. It has a wide adaptation capacity and can grow up to an altitude of 2000 m above mean sea level during summer season. It has a short generation time, fastest among all small millets in growth and completes the life cycle from seed to seed in 45-60 days however, may take longer time under northern hill zone. Several varieties of finger millet and barnyard millet have been released from ICAR-VPKAS, Almora for pan India cultivation (Table 2).

Table 2. Improved varieties of small millets developed by ICAR-VPKAS, Almora and suitable for all finger millet and barnyard millet growing states of the country

Crop	Name of the variety	Characteristics
Finger millet	VL *Mandua* 149	Released for all the finger millet growing areas except Tamil Nadu and Andhra Pradesh in year 1991 by CVRC. It has an average yield of 20-25 q/ha and is resistant to blast disease. Owing to its wide adaptability, it is still a popular variety and was national check for more than 20 years. It has open ears with long fingers.
	VL *Mandua* 347	It is an early maturing (<100 days) cultivar released for cultivation in six states including Uttarakhand. It has higher iron (7.9 mg/100 g) and zinc (3.56 mg/100 g) content in comparison to national check VR 708. The yield potential of the variety is 20-25 q/ ha and is moderately resistant to neck and finger blast disease.
	VL *Mandua* 352	It is also an early duration (<100 days maturity), high yielding variety (25-30 q/ha). This variety has been released for all finger millet growing states except Tamil Nadu and Maharashtra. It is moderately resistant to finger and neck blast. This variety is suitable for contingent crop planning.
	VL *Mandua* 376	It is also an early duration (<100 days maturity), blast resistant variety with high yield potential (28-35 q/ha). This variety has been released for all finger millet growing states.
	VL *Mandua* 379	It is also an early duration (<100 days maturity), blast resistant variety with high yield potential (26-35 q/ha). This variety has been released for North zone finger millet growing states.
Barnyard millet	VL *Madira* 172	Released for Uttarakhand, Karnataka and Gujarat by CVRC in 2000. It has an average yield of 20-22 q/ha and also possess high fodder yield of 40 q/ha.
	VL *Madira* 207	Released for cultivation in all barnyard millet growing states except Gujarat and Tamilnadu by CVRC in the year 2008. It has an average yield of 16-19 q/ha and is tolerant to grain smut.

Post harvest management

Threshing is a difficult task in almost all small millets and is one of the main reasons for decline in its acreage. In fact threshing of these crops is drudgery prone. To overcome the difficulty in threshing, ICAR-VPKAS has developed, Vivek *Mandua*/ Madira Thresher cum pearler 1 that can thresh as well as pearl grains of finger millet, barnyard millet, proso millet and foxtail millet. Threshing and pearling of finger millet are done simultaneously, whereas in case of foxtail millet, barnyard millet, and proso millet, threshing and pearling are done separately. The machine has threshing capacity of 60-80 Kg and pearling


Finger millet crop (VL Mandua 376) in Uttarakhand hills


Barnyard millet (VL Madira 172) in Uttarakhand hills

capacity of 80-100 kg grains of finger millet in one hour. The machine has similar threshing capacity for barnyard millet with dehusking capacity of 2.5-4.0 kg grains per hour. Two models of this machine *i.e.* Electric operated and Engine operated are available. The machine significantly reduces work load and time for post harvest processing of small millets.

Nutritional value

Millet is highly nutritious, non-glutinous and considered as warming grain that helps to heat the body in cold or rainy seasons. All the small millets contain moderate level of protein. The protein content of foxtail millet and proso millet is more than rice and comparable to wheat. The millet protein has well balanced amino acid profile and good source of methionine, cystine and lysine. The characteristic of slow digestion of complex carbohydrates in millets indicates that these crops can be consumed by diabetic and heart patients. Finger millet has thirty times more calcium than rice whereas every other millet has at least twice the amount of calcium compared to rice. Similarly, foxtail and little millet are rich in iron. While most of us go for pharmaceutical pills and capsules of beta carotene, millets offer it in abundant quantities. The much privileged rice, ironically, has zero quantity of this precious micronutrient.

A fertile soil alone does not carry agriculture to perfection.

- Elias Hasket Derby

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Agriculture is at the core of the state.

- Dave Cook

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Agriculture is the process of turning eco-systems into people.

- Toby Hemenway

Millets and *in-situ* moisture conservation: A key to fight drought caused by climate change

Raj Pal Meena, Suraj Goswami, K. Venkatesh, Vishnu Kumar and Ankita Jha

Growing more cereal crops with limited water resources for feeding the surge oaring population has turned out to be alarming. Production of more food with less water is one of the great challenges, especially for arid and semi arid regions. Ground water level is declining rapidly and surface water is also under dwindling situations due to increased evapo-transpiration as a result of global warming and disturbed rainfall pattern.

The macro level changes occurring in the recent past has led to climate change and increased detrimental effects on agricultural activities and productivity. Another notable change in agriculture management is the stretching of the production cycle all round the year; due to which the water requirement has gone up many folds and the slightest failure of monsoon leads to devastating effects on the crops, unlike earlier situations where a minimum crop was always guaranteed. Drought and drought like situations always loom around but with the arrival of monsoon, the menace of the drought has become the thing of the past. Everyone sleeps till the next summer to wake up only to put the blame on nature or others. Little efforts from our part would go a long way in managing drought and flood like situations.

There are two factors which affect crop production due to irrigation *viz*., water requirement of the crop and water management. First factor can be managed by using other crops having less water requirement and having the potential to feed the population. Millet crops require less water compared to other cereal crops. So there is an emphasis on growing of millet crops to feed the growing population while coping up with impact of climate change and global warming. Millets are also considered as drought and heat tolerant, suitable for water scared regions. Management of crop, irrigation requirement, soil moisture conservation, different tillage practices to retain maximum rainfall water into the soil are emerging issues for efficient water management practice. Crop water demand of different crops has been mentioned in Table 1 prove that millet crops have maximum water use efficiency.

Table 1 Crop water demand for different crops

Crop	Effective root zone	Water demand (mm)	Water use efficiency (kg/ha/mm)
Rice	Shallow (60 cm)	1200	3.7
Maize	Deep (120 cm)	625	8.0
Sorghum	Deep (120 cm)	500	9.0
Pearl millet	Deep (120 cm)	500	8.0

Source: Rao and Rana (1987)

Using crop with low water demand with precise water management can be a key to solve water constraint issue. It acts as a robust tool to fight against drought stress and thus can be beneficial for the arid and semi arid regions. Water use efficiency of different crops including millets affected by different agronomical practices such as plant density, row spacing, genotype, scheduling and methods of irrigation etc. Different moisture conservation practices such as deep ploughing, ridge and furrow

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system and use of bulky manures like FYM, green manure, vermi compost, oil cakes, crop residues etc increase the water holding capacity of soil.

Mulch reduces the rate of evapo-transpiration from soil and ultimately reduces the water losses. It was also found that there is an increase in yield of the sorghum as well as 15% saving of the irrigation water in mulched soil as compared to the un-mulched soil. Tillage practice increases the water holding capacity of soil; which ultimately is available to the plant/crop.

Various management practices are there to increase the soil moisture reserve by holding the rain water in soil profile. This can be achieved by making the running water walk, walking water to stand and standing water to sleep". Incorporating these principles of in-situ moisture conservation with millet production can be an excellent tool in water scarce regions.

Principle 1: Making running water to walk

The mentioned phrase refers to the decline in speed of running water so as to make it walk. It can be achieved by constructing any kind of barrier/ obstruction in the path of flow of rainwater. Nature restricts the speed of moving water through vegetation having extensive root system and foliage. Therefore, in order to slow down this process we should keep in mind and follow the rules and principles of nature. A vegetative shield all along the border of the farm may be built in order to ensure sufficient protection against sun and wind and also constitute enough green matter not only for mulching and composting but also for botanical decoctions against pest and diseases or as nutrients.

In fields including undulating areas or hilly terrains, contour trenching (Fig 1a), bonding, terracing with vegetation(Fig 1b), establishment of gully plugging or any other suitable mechanical structures are effective means to slack off the speed of running water.

Fig. 1a : Contour trenching at hilly area. 1b : terracing with vegetation hills

Principle 2: Making walking water to stand

Here, our motive is to store water in the soil profile or soil layers. In the field, it can be achieved by allowing maximum infiltration of the rain water into the soil layers. Thus, it is imperative that there should be sufficient soil above the hard crust. It is worth remembering that it takes thousands of years to make one inch of top soil and the same could be washed off in a few years due to excess and inappropriate human intervention. Deep summer ploughing before monsoon is a reliable technology for storing maximum rain water in soil profile during the monsoon period.

Deep summer ploughing keeps top and sub soil open and breaks the hard crust which facilitates fast infiltration of water in deep soil profiles. Besides water conservation or storing rainwater in soil profile, summer ploughing also serves as a means for natural pest (insects, pathogens and weeds) control in agriculture. Therefore, this technology also helps bring down the cost of cultivation.

Fig. 2a : Walking water stand in fields

Mulching the soil with the crop residues or growing of cover crops especially legumes, not only facilitates water to stand in soil but also protects the soil from erosion and also improves fertility. Thus through these techniques, walking rain water is provided with adequate time to stand in the soil and infiltrate down (Fig. 2a).

Digging of water pits at regular intervals also helps walking water stand in the field for longer time encouraging infiltration. Water pits of suitable size can be made in gentle sloping lands for example *viz*. 2'× 2' × 2' (the size may reduce or increase depending on the field situation) and about 100-150 could be made in one hectare of land. A word of caution is that in too steep slopes, land-slides may occur if too much of water is allowed to stand in the soil (Fig. 2b).

Fig. 2b : Walking water stand in fields

Principle 3: Making standing water to sleep

This expression is meant to denote the withdrawal of destructive energy of the rain water so that it remains still in a storage system. The storage system could be a rain water harvesting well, check dam, sub-surface dykes, ponds (Fig. 3a) or polythene lined storage ponds (Fig. 3b), percolation tank, mini percolation tank (MPT), cement tanks etc. The stored water is judiciously used in times of need for sustaining production or at least to provide life saving irrigation.

Fig. 3a

Fig. 3b

Fig. 3a : Pond build to store water. 3b : Pond build up by the use of reinforcement and polyethylene

Fig. 4 : Judicious use of water

Judicious use of stored water

Conventional methods of irrigation require huge amount of water as well as more labor to implement it (Fig. 4). Modern systems of irrigation such as drip, sprinkler, micro-sprinkler, rain-gun, pivot, mist or fogger increases water use efficiency and also provides opportunity for fertigation or application of pesticides. These can be practiced with other agronomic practices in combination to ensure higher water use efficiency. Mulching of the farm with dried leaves or agro-wastes prevent soil moisture loss. Application of organic manures such as farm yard manure, green manure, compost, leaves of trees etc. enhance humus content of the soil thereby boosting the water holding capacity of soil.

Different losses occur during the hydrologic cycle, so it is always better to use rainwater before it returns back into the hydrologic cycle system. Rainwater is an indispensable source which needs to be conserved at any cost. We can conserve it in urban and rural areas at both individual and community levels. Public participation shall ensure water movement at a mass level which shall relieve us from this formidable problem. Using the above mentioned techniques with regards to growing millet can increase the millet production with less water use. Fusion of low water demand crop with water saving techniques will help us to beat the impact caused due to climate change.

Nutrient management techniques for enhancing the production of small millets

Alok Kumar Singh, Abhishek Singh and Rakesh Singh Sengar

Small millets are highly nutritious and even superior to rice and wheat in many constituents. Finger millet is the richest source of calcium (344 mg/100g) and other small millets are a good source of phosphorus and iron too. The millet protein has a balanced amino acid profile and a good source of methionine, cystine, and lysine. Six small millets that are most important in India are Finger millet, Foxtail millet, Proso millet, Kodo millet, Barnyard millet and Little millet.

In India, small millets are cultivated on 6.19 lakh ha with production of 4.42 lakh tones with a productivity of 714 kg/ha. In Gujarat, small millets occupies an area about 0.22 lakh ha with a production of 0.28 lakh ha and productivity of 1273 kg/ha. The major little millet growing states are Karnataka, Andhra Pradesh and Tamil Nadu. In Gujarat, little millet cultivated mainly in hilly, dry land and tribal area of Dang, Navsari, Panchmahal and Valsad districts.

To make up for the nutrient deficiencies commonly found in millets Calcium Ammonium Nitrate (CAN) can be made available to the acidic soils where this crop is grown mostly in hilly area. Phosphorous is given as a basal dose at the time of sowing. Source of K available to the crop is in the form of Muriate of Potash (MOP), and other micronutrients, especially iron and zinc should also be applied to the soils in which small-millets are grown. Other ways of nutrient management in millets is by intercropping of grain legumes, growing a green manure crop and incorporating it into the fields and use of farmyard manure (FYM).

Sl.No.	Common name	Scientific name	Chromo. no.	Place of domestication
1.	Indian Barnyard millet	*Echinochloa frumentacea* Link.	2n=54 (6x)	India
2.	Proso millet	*Panicum miliaceum* L.	2n=36 (4x)	Central Asia, India
3.	Little millet	*Panicum sumatrense* Roth.	2n=36 (4x)	India
4.	Kodo millet	*Paspalum scrobiculatum* L.	2n=40 (4x)	India
5.	Foxtail millet	*Setaria italica* L. P. Beauv.	2n=18 (2x)	Central Asia, India
6.	Finger millet.	*Eleusine coracana* L. Gaertn	2n=36 (4x)	Ethiopia, African
7.	Japanese Barnyard millet	*Echinochlo autilisohwi* et yabuno.	2n=54 (6x)	East Asia
8.	Korne	*Brachiaria ramosa* (L.)	-	India

The nutrient deficiencies commonly found in millets are those of nitrogen (N) and phosphorus (P) followed by potassium (K), which are of considerable importance in plant nutrition. Nitrogen deficiency is the most prominent followed by P deficiency, largely due to acidic nature of hill soils. Due to the coarse texture of soils, potassium deficiency occurs as it has the tendency to leach. Also during a dry spell, when a millet crop is grown in rainfed conditions, the plants can suffer from K

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deficiency in spite of the soils being high in available potassium. This occurs, as the movement of K gets impaired to the roots under moisture stress conditions. Nitrogen is the major nutrient required for plant growth and also the most lacking in terms of availability to the plants. Urea is the most used form of N supply, but in acidic conditions Calcium Ammonium Nitrate (CAN) is a better option.

Barnyard millet crop

Added advantage of CAN is that it also provides calcium to the plants and soils, which is otherwise deficient in acidic soils. All the millets respond to N application with mostly responding to 40 kg N/ha. Nitrogen should be placed as basal fertilizer either 2 to 3 cm below the seed or in a side band 4-5 cm away from seed row and 5-7 cm deep. In finger millets when fertilizers are placed in the same row as the seed or in the side row using seed cum fertilizer drill, there is a 30% increase in the grain yields when the same amount is broadcasted. Applying nitrogen in splits during crop season results in higher yields. In hills the soils are coarse textured therefore only a part of N at sowing and the remaining amount of N in 2-3 splits are to be used so as to minimize the leaching losses of N when there are heavy rains. The whole amount of phosphorus is given as a basal dose at the time of sowing. Generally, the hill soils are acidic therefore the water soluble P gets fixed and becomes unavailable to the plants. Seed inoculation with P-solubilizing microorganisms is the best way to ensure P availability to the crops throughout their growing season. Muriate of Potash (MOP) is the dominant source of K available to the farmers. Potash application to millets is made as part of basal

Finger millet

dressing applied by sub surface placement. But in hills it has been observed that farmers don't use any K containing fertilizer. Potassium imparts drought resistance to plants as it regulates stomatal opening and under rainfed conditions K application will be very beneficial in mitigating the effects of drought/moisture stress. There is a very good response to micronutrient application, especially of iron and zinc. Nutrient interactions between different elements are also an important aspect in terms of plant nutrient uptake. Applying only one nutrient and not applying other nutrients will not produce high yields. Hill soils, which have P fixation problem, will not give high yields when only N is given, as is the case with most of the farmers. So N should never be given alone as N and P have synergistic effects on plant nutrition. Nutrient management assumes greater importance when the millets are grown in rainfed conditions. In such conditions judicious use of nutrients especially P and K assumes greater significance as these nutrients improve the water use

Foxtail millet

efficiency. When the water use efficiency of plants is increased the grain yields and dry matter yields are increased. Increase in water use efficiency due to P application is greater in coarse textured soils than on fine textured soils and this assumes great importance in farming systems as hill soils have low water holding capacity due to their coarse texture. Root growth promoted by P application, results in water absorption from lower layers, which is very important during water stress conditions. Potassium also improves water use efficiency as it regulates stomatal openings of the leaves and helps to maintain crop yields under moisture stress. For effective nutrient management it's very important to conserve the soil moisture, be it by mulching or banding etc. Nutrient management in millets can be greatly enhanced by including grain legumes in intercropping or in crop sequences. These fix atmospheric nitrogen and make it available to the succeeding non-leguminous crops. Wherever millet is grown after leguminous crop, there is a significant increase in yield. The benefit of taking leguminous crop is that the leguminous crop makes available 15-20 kg N/ha for the succeeding millet crop. Among the millets, pearl millet is the most efficient crop to use residual N from the preceding leguminous crop, closely followed by sorghum. In rainfed areas the prospects of growing a green manure crop and incorporating it into the fields is rather limited as the decomposition will be totally dependent on the rains. Therefore partial green manuring can be done by sowing an early duration leguminous crop (green gram or cowpea) with the onset of monsoon and after first harvest of the pods the plants can be incorporated into the soil. The millets grown in such kind of cropping systems have to be grown in nursery and millets can be transplanted into the soil. This will also help in timely sowing. In terms of economics it's more beneficial also as the grains of pulses fetch higher prices than cereals and also there is no need to apply nitrogenous fertilizers to these legumes. The intercropping also provides greater stability to the system because the chances of total failure of a single crop are greatly reduced. The beneficial effects of farmyard manure are known to all. Therefore FYM @ 10 t/ha with only 50% of the recommended NPK doses produce similar yields as compared to 100% NPK. It will save precious money of the marginal farmers and sustain the fertility of the soil. In mountainous agricultural system where most of the land is rainfed FYM can play an important role in moisture conservation. Seed inoculation with azotobacter or azospirillum is also very beneficial and can be adopted by farmers practicing organic farming. These biofertilizers will provide N to the plants and also solubilize the P fixed into the soil. Azotobacter and azospirillum also secrete growth-promoting hormones, which will further promote plant growth. Two kilograms of azotobacter or azospirillum is mixed with 25 kg soil and 25 kg FYM and then it's applied to one hectare soil at the time of last ploughing and just before sowing. Farmers employing these nutrient management practices in millets will reap better yields and also sustain the soil fertility.

When the Nobel Peace Prize Committee designated me the recipient of the 1970 award for my contribution to the 'green revolution,' they were in effect, I believe, selecting an individual to symbolize the vital role of agriculture and food production in a world that is hungry, both for bread and for peace.

- Norman Borlaug

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"When tillage begins, other arts follow. The farmers, therefore, are the founders of human civilization."

- Daniel Webster

Improved production technology of finger millet to strengthen climate resilience and nutritional security in Bundelkhand region

D.C. Joshi, Manoj Parihar, R.P. Meena, Hanuman Ram and Kiran Rana

Agriculture is demographically the broadest livelihood option in Bundelkhand region of Uttar Pradesh. The Bundelkhand region occupies over 70,000 sq. km in 13 districts of Uttar Pradesh and Madhya Pradesh, where agriculture has always played a significant role in improving the social as well as economic fabric of the local farming communities. Many districts of the state are recognized as treasure trove of biodiversity, yet it has limited infrastructure and economic development. Out of the total cultivated area in the region, approximately 70% is rainfed. An insight into the rainfed regions reveals a grim picture of poverty, water scarcity, rapid depletion of ground water table and fragile ecosystem. Ongoing and long term predicted climate change scenarios are likely to have serious effects on livelihoods, where rising temperatures, variability and changes in precipitation are severely affecting crop production. For instance, almost all districts of the region have suffered continuous drought between the year 2003 and 2010 and a second spell of severe drought in the year 2014.

Keeping in view the frequent moisture stress coupled with hot and harsh climatic conditions, there have been many crops and farming practices which were adopted and followed for millennia, but are in the process of being abandoned in favour of cash crops. Earlier the millets were main agricultural crops in this region, but vanished over time due to lack of suitable varieties, low yield, marketing and other reasons. However, after the introduction of high yielding varieties of cereals in the early eighties, a huge drop has been observed in the cultivated area of traditional millets such as *kodon*, *sawa*, *kutki* and *ragi* in the region. At present major crops (maize, wheat and potato) are the major food sources for a majority of people in the region. The mono-cultural agro-ecosystems of these major crops have led to narrowing the crop genetic base in the region. It has also resulted in high vulnerability of modern cropping systems to the predicted climate change and accompanying weather extremities. The nutritional status of the rural masses is also not satisfactory due to the over dependence on these crops for dietary requirements.

Millets are especially rich in iron, zinc and calcium, and have other dietary qualities that can help stave off anaemia, celiac disease and diabetes. The millets are not only nutrient rich but also extremely resilient to face water stress and other abiotic stresses. The high nutritional value coupled with the hardiness makes them desirable food security climate-smart crops for the region. In the light of unparallel nutritional value and tolerance to abiotic stresses, there is an urgent need to revive millet cultivation in Bundelkhand region. Among the six small millets, finger millet is widely cultivated crop for tropical and subtropical climatic regions. Finger millet is known as 'famine crop' because it serves as a source of assured harvest and an indispensable crop in specifc ecosystems such as dry lands, hills, tribal and marginal areas. The crop provides food grain as well as straw, which is a valued animal feed in dry lands. Besides, it is a fairly climate-resilient, drought-tolerant crop, and its grain has an extended shelf life of several years without significant damage by storage pests.

Nutritional value and nutraceutical properties of finger millet

Finger millet grains have exceptionally high nutritional value. They contain about 5–8% protein, 65–75% carbohydrates, 15–20% dietary fibre and

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2.5–3.5% minerals. The grains contain on an average 7% protein, which varies from 4.88 to 15.58% and contains 44.7% of the essential amino acids. The dietary fibre content of finger millet grains (11.5%) is higher than the fibre content of brown rice, polished rice, and many types of millet too. Among minerals, finger millet grains are exceptionally rich in calcium (350 mg/100 g) compared to all cereals and other millets, and its grains also contain good amount of phosphorus, potassium and many other trace elements and vitamins (Fig 1). Finger millet contain good amount of iron and therefore, it is also beneficial for the people who are having low haemoglobin level. Carbohydrates of finger millet are reported to have the unique property of slow digestibility and can be regarded as food for diabetic patients. Seed coat of finger millet possesses anti-cancer properties due to the abundance of polyphenols and antioxidants. All these nutraceutical properties along with climate resilient nature provide socio-economic importance to finger millet for subsistence and marginal farming system of semi-arid regions and dry lands.

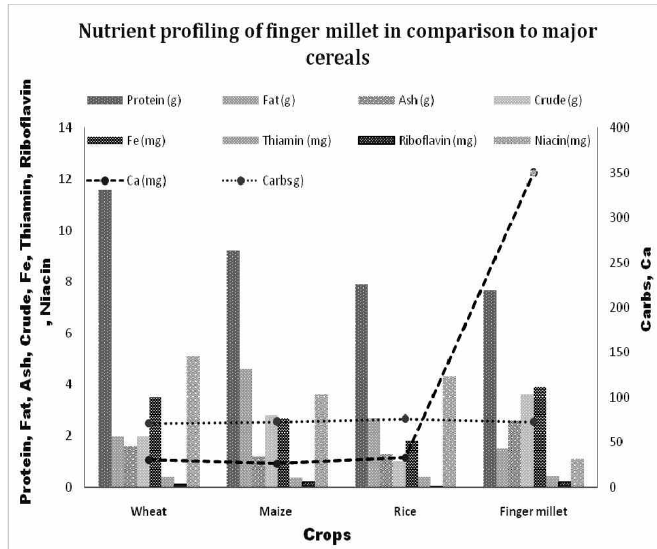


Fig.1: Nutritional value of finger millet in compared to three major cereals (rice, wheat and maize). Sources (FOA 1995; U.S. National Research Council/ NAS. 1982: USDA/HNIS. 1984)

Improved production technology

High yielding cultivars:

The different varieties of finger millet are developed and released to meet the specific need of various regions. The lists of improved and popular varieties (Fig. 2) for various states are given in Table 1:

Table 1: popular verities of finger millet recommended for different states

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 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.	Orrisa	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.	Chhattisgarh	Indira Ragi-1, Chhattisgarh-2, BR-7,GPU 28, PR202, VR 708,VL 149, VL 315, VL 324, VL 352, VL 376, OEB-526, OEB-532
8.	Maharashtra	Dapoli 1, KOPN 235, KOPLM 83, Dapoli-2
9.	Gujarat	GN4, GN5, GNN6, GNN-7
10.	Bihar	RAU8, VL-379, OEB-526,OEB-532
11.	Madhya Pradesh	GPU 28,PR 202, VL 352, VL 376, VL-379

VL *Ragi* 347 **VL *Ragi* 352**

VL *Ragi* 376 **VL *Ragi* 379**

Figure 2: Improved varieties of finger millet developed from ICAR-VPKAS, Almora for all the finger millet growing states of the country

Improved agronomic practices

Soil and Climate

Finger millet can be grown in very poor to very fertile soil and is best suited to loamy alluvial soil with good aeration and drainage. The soil having good organic matter and pH value ranged from 4.5 to 8.0 is to be considered suitable for finger millet cultivation. This crop is also found tolerant to soil alkalinity up to an extent. It is heat preferable crop and requires tropical to subtropical climate. For its proper development and growth, mean temperature of 26-29 ℃ is required. Finger millet is mostly rainfed crop and grown under *Kharif* season. It is normally sown in the month of June in Uttar Pradesh and Uttarakhand and in April-May in hills at higher altitudes of North West Himalaya. It is also grown in winter season (*Rabi*) by planting in September-October in Karnataka, Tamil Nadu and Andhra Pradesh and as a summer irrigated crop by planting in January – February in Karnataka, Tamil Nadu, Andhra Pradesh and Bihar.

Tillage

Tillage operation should be performed in the month of April or May, with mould board plough followed by wooden plough. To conserve soil moisture and for smooth seed bed preparation, land smoothening is necessary before sowing. Ideal seed depth is up to 2.5 cm and they take one week time to germinate.

Seed rate and seed treatment

Seed should be well treated with thiram @ 2.5 g kg^{-1} of seed before application. The ideal seed rate for drill sowing is 10 kg ha^{-1} while for preparing nursery for transplanted condition is 5 kg ha^{-1}. In general, seedlings of 21-25 days old are ideal for transplanting in rows of 22.5 – 25 cm apart, with 2 seedlings per hill at every 10 cm within row. Sowing by seed cum fertilizer drill is advantageous for line sowing besides efficient utilization of applied nutrients. The optimum plant population per ha is 4-5 lakh plants to obtain higher yield. Under rainfed condition if germination percentage is poor then proper plant population is prerequisite while under normal condition, thinning operation should be performed after 20-27 days of sowing. However, under transplanted condition, maintenance of optimum plant population is not necessary.

Sowing method

Finger millet sowing is mostly done by line sowing as it helps in easy inter cultivation operation to manage weed problem effectively. For line sowing, appropriate spacing is 22.5 to 30.0 cm between row and 7.5 to 10.0 cm spacing between plants is recommended. Another method of sowing in finger millet is transplanting under irrigated condition.

Manuring and fertilization

The FYM application is necessary to maintain soil physical, chemical and biological health in good condition. Generally, 5 to 10 t ha^{-1}manure application is recommended before one month of sowing. However, finger millet responds well to fertilizer application @ 60 kg N, 30 kg P2O5 and 30 kg K_2O under irrigated and 40, 20 and 20 N, P_2O_5 and K_2O respectively under rainfed conditions. In irrigated condition, 50% nitrogen is to be applied during sowing and the remaining 50 % in two split at 25 and 45 days after sowing while entire amount of P_2O_5 and K_2O are to be applied at sowing. Under rainfed condition, two splits of N are recommended where 50% at sowing and remaining 50% at 35 days after sowing.

Irrigation

In *kharif* season, finger millet does not require irrigation. However, irrigation scheduling depends on weather condition and soil type. Generally, light texture soils needs to be irrigated in 6 to 8 days interval while heavy texture soils in 12-15 days

Weed management

Under rainy season, weed control is major problem in finger millet. Weed problem can be managed effectively using cultural and mechanical practices. In broadcasted crop, two hand weedings and in line sowing, inter cultivations with 1 effective hand weeding is necessary. Under irrigated condition, for pre emergence weeds, spray of oxyflurofen @ 0.1 lta.i /ha or Isoproturon @ 0.5 kg a.i.ha^{-1} while for post-emergent spray of 2, 4-D sodium salt @ 0.75 kg a.i.$ha^{-1}$is effective.

Cropping system

Finger millet can be rotated with legume crops such as green gram or black gram in Bundelkhand region. Millet-millet rotation should be avoided to maintain the overall sustainability of agro-eco system. For intercropping, finger millet can be grown with soybean, pigeon pea and field bean while regarding cropping sequence, Potato–paddy-finger millet and ragi – onion – ragi cropping sequence proved highly remunerative in Bihar and Deccan plateau, respectively.

Disease and pest management

The major disease of finger millet crop is blast caused by *Pyricularia grisea* mainly under *kharif* season. This disease can be effectively managed by using resistant verities such as resistant varieties like GPU 28, GPU 26 and GPU 48 or by seed treatment with carbendazim @ 2g kg^{-1} before sowing or spraying the nursery with carbendazim (0.05%) or kitazin (0.1%). Another important disease are brown spot caused by *Drechsler anodulosa*, mottle streak and streak virus, foot rot (*Sclerotium rolfsii*), downy mildew or green ear (*Sclerosporama crospora*) and grain smut (*Melanopsichium eleusinis*).

The major pest of finger millets and their management are listed below:

1. Army and cutworm: They appear during early crop stages and attack on seedling base. At later stages, they become defoliator. These pests are cyclic in nature and can be controlled using Malathion 5% @ 24 kg ha^{-1} or Endosulfan 4% @ 12 kg ha^{-1}.
2. Leaf aphid: Aphids are actually sucking type pests and they cause damage only at early stage upto 30 days of seedling. Leaf aphid can be managed by spraying Dimethioate (0.05%) or Endosulfan (0.07%) or Quinolfos (0.05%).
3. Stem borers: Their larva attack on stem and form dead heart. Spray of Dimethioate (0.05%) or Monocrotophos (0.04%) are used to control them.
4. Ear caterpillars: They appear during dough stage and remain till harvesting which results in half eaten grains. Ear caterpillars affected grains are prone to further attracts by saprophytic fungi. For management purpose dust of Malathion 5% @ 24 kg ha^{-1}or or Endosulfan 4% @ 24 kg $ha^{-1}$are effective.

Harvesting and threshing:

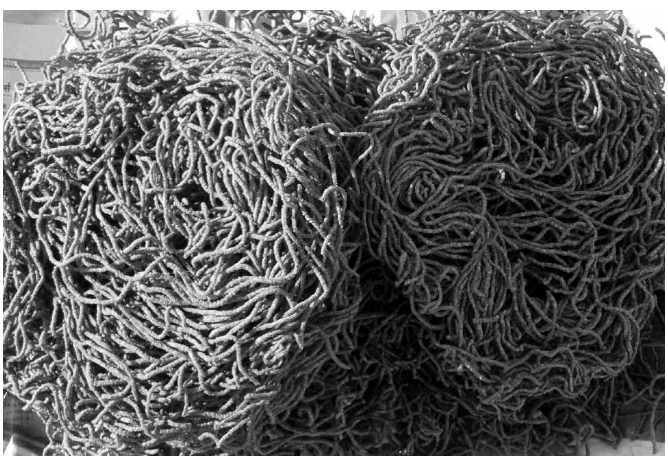
Finger millet crop matures in 3- 5 months which mainly depends on the characteristics of variety. When 80% earheads become brown, they are harvested and then drying is done in sun for 3 to 4 days followed by threshing. The average yield of finger millet under rainfed condition is 10-15 q $ha^{-1}$and under irrigated condition 40 to 50 q ha^{-1}. Threshing is a difficult task in finger millet and is one of the main reasons for decline in its acreage. In fact threshing of finger millet is drudgery prone. To overcome the difficulty in threshing, ICAR-Vivekanada Institute of Hill Agriculture, Almora has developed, Vivek *Mandua*/ Madira Thresher cum pearler (Fig. 3) that can thresh as well as pearl grains of finger millet, barnyard millet, proso millet and foxtail millet. Threshing and pearling of finger millet are done simultaneously, whereas in case of foxtail millet, barnyard millet, and proso millet, threshing and pearling are done separately. The machine has threshing capacity of 60-80 Kg and pearling capacity of 80-100 kg grains of finger millet in one hour. Two models of this machine *i.e.* Electric operated and Engine operated are available. The machine significantly reduces work load and time for post harvest processing of small millets.

Fig.3: Threshing of finger millet through traditional practice and finger millet thresher cum pearler

Processing and value addition

Food processing is a process employed to improve the food grain quality and reducing the antinutrients content by transforming them into other forms such as sprouting, roasted, popped, porridges, salted ready-to-eat grains and fermented foods. Using value addition techniques, consumption and marketing of finger millet can be enhanced effectively (Fig. 4). Several value addition techniques are available for finger millet and some of them are listed below

1. **Weaning food:** Weaning food is prepared using mixture of finger millet, Bengal gram and green gram flour. This preparation is rich in calcium and amino acids and used for infant feeding, in beverages and milk.
2. **Fermented food:** Ragi is broadly utilized for the preparation of fermented food items such as Idli and Dosa which are very popular in various part of country. Addition of ragi not only enhances the taste but also improve the calcium, iron, protein and fiber content. Many fermented foods are prepared using malted and sprouted grains of finger millet.
3. **Extruded products**: This is novel technology for the preparation of value added products under high pressure and temperature for transforming the starch properties. Ragi flour has good extrusions characteristics and their mixture with soy and wheat flour is used for the preparation of noodles and pasta. Addition of finger millet flour has its own advantages due to low glycemic response which is good for diabetic patients.
4. **Bakery products**: Nowadays, finger millet based bakery products such as bread, nankhatai, biscuits and muffins are popular in market due to greater availability of micronutrients, dietary fiber and phytochemicals in ragi grain seed coat.



Finger millet Namkeen

Finger millet biscuits

Figure 4: Value added products of finger millet (namkeen and biscuits); hands on training provided to farmers in value added products by ICAR-VPKAS, Almora

Role of small millets in nutritional security of the nation

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Abstract : Small millets are an often overlooked staple food for millions living in the harsh, food-insecure regions of the developing world. They are rich in micronutrient and account for about 10% of global millet production. Being extremely resilient in facing the drought and other abiotic stresses, making them valuable food security crops for millions living in marginal environments.

Introduction

Small-grained cereal grasses are collectively called 'Millets', one of the oldest cultivated foods known to humans. There are two main groups of millets first group consist of major millets (sorghum and pearl millet) and second group has small millets this categorization is based on the grain size and is also an indication of the area under cultivation of these crops, but both (major and small millets) have traditionally been the main components of the food basket of the poor people, especially in dryland farming system in India and elsewhere. Among these, small millets are known by different vernacular names in different parts of the country (Table-1).

Table-1: Vernacular names of small millets in different parts of the country.

Language	Small millets					
English	Finger millet	Little millet	Kodo millet	Foxtail/ Italian millet	Barnyard millet	Proso millet
Hindi	Mandua	Kutki	Kodon	Kangni, Kakum	Sanwa, Jhangon	Barre
Sanskrit	Nandimukhi, Madhuli	-	Kodara	Kanguni	Shyama	Chiná
Kannada	Ragi	Same	Harka	Navane	Oodalu	Baragu
Tamil	Kelvaragu	Samai	Varagu	Tenai	Kuthiravaali	Panivaragu
Telugu	Ragulu	Samalu	Arikelu, Arika	Korra, Korralu	Udalu, Kodisama	Varigulu, Varagalu
Malayalam	Moothari	Chama	Varagu	Thina	-	Panivaragu
Marathi	Nachni	Sava	Kodra	Kang, Rala	Shamul	Vari
Gujarati	Nagli, Bavto	Gajro, Kuri	Kodra	Kang	Sama	Cheno
Bengali	Mandua	Kangani	Kodo	Kaon	Shamula	Cheena
Oriya	Mandia	Suan	Kodua	Kanghu, Kora	Khira	Chinna
Punjabi	Mandhuka, Mandhal	Swank	Kodra	Kangni	Swank	Cheena
Kashmiri	-	Ganuhaar		Shol	-	Pingu

The group of small millets is represented by six different species, namely finger millet (*Eleusine coracana*), little millet (*Panicum sumatrance*), kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italic*), barnyard millet (*Echinochloa frumentacea*) and proso millet (*Panicum miliaceum*).

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Barnyard millet
[*Echinochlo acolona* (L.) Link] and
[*Echinochloa crus-galli* (L.) P. Beauv.]

Proso millet
[*Panicum miliaceum* L.]

Little millet
[*Panicum sumatrense* Roth. ex. Roem. &Schult.]

Kodo millet
[*Paspalum scrobiculatum* L.]

Foxtail millet
[*Setaria italica* (L.) Beauv.]

Eleusine coracana

Geographical distribution:

Among small millets, finger millet is the most important crop grown in many states of Southern, Central, Eastern, Western and Northern India from sea level to 8000 feet altitude. The loss of area under finger millet has been less on account of improvement in productivity. On the contrary the area under other small millets has reduced by more than half with proportionate reduction in total production. The productivity remained low and stagnant around 450 kg/ha. Recent and accurate statistics regarding each of the small millets is still lacking by far it is clear that more than 60% of area under small millets is occupied by finger millet, distantly followed by little and kodo millets (just above 10%) and followed by barnyard, foxtail and proso millets.

Though small millets are grown in almost every state of the India,the distribution of individual millet is not uniform. The kodo, little and foxtail millets are grown widely in Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Madhya Pradesh and Maharashtra. In Madhya Pradesh, both kodo and little millet are predominant, while foxtail millet is important in Andhra Pradesh and Karnataka. Barnyard millet and proso millet are grown largely in hills of Uttar Pradesh, North-Eastern region and plains of North Bihar and Western Uttar Pradesh and Maharashtra.

Properties and nutritional profile:

The small millets are small seeded grains that resemble paddy or rough rice in the morphological features of kernel. The kernel consists of distinct husk, bran and endosperm tissues. Embryo is a distinct tissue, but its proportion in the kernel is around 2%. The husk is non-edible similar to the husk in rough rice or paddy whereas bran may be part of the edible component but is separated to prepare milled millets for food uses. Normally, husk accounts to 15 to 20% of the kernel whereas the bran amount to about 5% and the endosperm to about 75% of the kernel, respectively. These grains are round to oval shaped and their 1000-kernel weight and volume range from 1.9 - 5.5 g and 1.3 - 3.8 ml, respectively. The seed coat and husk of foxtail, little and proso millet are generally of single entity with glossy appearance whereas kodo and barnyard millet contain multiple layered seed coat. Normally the seed coat of kodo millet is of brown colour, foxtail millet is yellowish whereas the other millets are greyish coloured. The husk is non-edible and unusually hard to digest similar to the husk in paddy, whereas the bran is edible. To prepare edible items out of millets, the husk is separated by milling and along with that generally, the bran is also separated similar to milled rice. Hulling does not affect the nutrient value as the germ stays intact through this process.

Small millets are more nutritious compared to fine cereals. Finger millet is the richest source of calcium (300-350 mg/100 g) and other small millets are good source of phosphorous and iron. The protein content ranges from 7 to 12% and fat content from 1 to 5.0% (Table-2). The millet protein has well balanced amino acid profile and good source of methionine, cystine and lycine (Table-3). These essential amino acids are of special benefit to those who depend on plant food for their protein nourishment. The millet grain contains about 65% carbohydrate, a high proportion of which is in the form of non-starchy polysaccharides and dietary fibre which help in prevention of constipation, lowering of blood cholesterol and slow release of glucose to the blood stream during digestion. Lower incidence of cardiovascular diseases, duodenal ulcer and hyperglycemia (diabetes) are reported among regular millet consumers. Millet grains are also rich in important vitamins *viz*., Thiamine, riboflavin, folin and niacin (Table-4) and are comparable to rice and wheat or even rich in some of the minerals (Table-5) as well as fatty acids (Table-6). Millets vary largely in composition of carbohydrates as proportion of amylose and amylopectin content vary from 16-28% and 72-84%, respectively (Table-7).

Table-2: Nutrient composition of millets compared to fine cereals (per 100 g).

Food gain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (KCal)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Finger millet	72.0	7.3	1.3	328	3.6	2.7	344	283	3.9
Kodo millet	65.9	8.3	1.4	309	9.0	2.6	27	188	0.5
Proso millet	70.4	12.5	1.1	341	2.2	1.9	14	206	0.8
Foxtail millet	60.9	12.3	4.3	331	8.0	3.3	31	290	2.8
Little millet	67.0	7.7	4.7	341	7.6	1.5	17	220	9.3
Barnyard millet	65.5	6.2	2.2	307	9.8	4.4	20	280	5.0
Sorghum	72.6	10.4	1.9	349	1.6	1.6	25	222	4.1
Bajra	67.5	11.6	5.0	361	1.2	2.3	42	296	8.0
Wheat (whole)	71.2	11.8	1.5	346	1.2	1.5	41	306	5.3
Rice (raw, milled)	78.2	6.8	0.5	345	0.2	0.6	10	160	0.7

(Source: Nutritive value of Indian foods, NIN, 2007).

Table-3: Essential Amino acid profile of different millets (mg/g of N).

Millet	Arginine	Histidine	Lysine	Tryptophan	Phenyl Alanine	Tyrosine	Methionine	Cystine	Threonine	Leucine	Isoleucine	Valine
Foxtail	220	130	140	60	420	-	180	100	190	1040	480	430
Proso	290	110	190	50	310	-	160	-	150	760	410	410
Finger	300	130	220	100	310	220	210	140	240	690	400	480
Little	250	120	110	60	330	-	180	90	190	760	370	350
Barnyard	270	120	150	50	430	-	180	110	200	650	360	410
Sorghum	240	160	150	70	300	180	100	90	210	880	270	340
Bajra	300	140	190	110	290	200	150	110	140	750	260	330
Rice	480	130	230	80	280	290	150	90	230	500	300	380
Wheat	290	130	170	70	280	180	90	140	180	410	220	280

(Source: Nutritive value of Indian foods, NIN, 2007).

Table-4: Vitamin profile of different millets.

Millet	Thiamin (mg)	Niacin (mg)	Riboflavin	Vit A (carotene) (mg/100g)	Vit B6 (mg/100g)	Folic Acid (mg/100g)	Vit B5 (mg/100g)	Vit E (mg/100g)
Foxtail	0.59	3.2	0.11	32	-	15.0	0.82	31.0
Proso	0.41	4.5	0.28	0	-	-	1.2	-
Finger	0.42	1.1	0.19	42	-	18.3	-	22.0
Little	0.3	3.2	0.09	0	-	9.0	-	-
Barnyard	0.33	4.2	0.1	0	-	-	-	-
Kodo	0.15	2.0	0.09	0	-	23.1	-	-
Sorghum	0.38	4.3	0.15	47	0.21	20.0	1.25	12.0
Bajra	0.38	2.8	0.21	132	-	45.5	1.09	19.0
Rice	0.41	4.3	0.04	0	-	8.0	-	-
Wheat	0.41	5.1	0.1	64	0.57	36.6	-	-

(Source: Nutritive value of Indian foods, NIN, 2007; *MILLET in your Meals*, http://www.sahajasamrudha.org/)

Table-5: Micronutrient profile of millets (mg/100g).

Millets	Mg	Na	K	Cu	Mn	Mb	Zn	Cr	Su	Cl
Foxtail	81	4.6	250	1.40	0.60	0.070	2.4	0.030	171	37
Proso	153	8.2	113	1.60	0.60	-	1.4	0.020	157	19
Finger	137	11.0	408	0.47	5.49	0.102	2.3	0.028	160	44
Little	133	8.1	129	1.00	0.68	0.016	3.7	0.180	149	13
Barnyard	82	-	-	0.60	0.96	-	3	0.090	-	-
Kodo	147	4.6	144	1.60	1.10	-	0.7	0.020	136	11
Sorghum	171	7.3	131	0.46	0.78	0.039	1.6	0.008	54	44
Bajra	137	10.9	307	1.06	1.15	0.069	3.1	0.023	147	39
Rice	90	-	-	0.14	0.59	0.058	1.4	0.004	-	-
Wheat	138	17.1	284	0.68	2.29	0.051	2.7	0.012	128	47

(Source: Nutritive value of Indian foods, NIN, 2007; *MILLET in your Meals*, http://www.sahajasamrudha.org/).

Table-6: Fatty acid composition of millets.

Millet	Palmitic	Palmoleic	Stearic	Oleic	Linoleic	Linolenic
Foxtail	6.40	-	6.30	13.0	66.50	-
Proso	-	10.80	-	53.80	34.90	-
Finger	-	-	-	-	-	-
Little	-	-	-	-	-	-
Sorghum	14.0	-	2.10	31.0	49.0	2.70
Bajra	20.85	-	-	25.40	46.0	4.10
Rice	15.0	-	1.90	42.50	39.10	1.10
Wheat	24.50	0.80	1.00	11.50	56.30	3.70

(Source: Nutritive value of Indian foods, NIN, 2007; *MILLET in your Meals*, http://www.sahajasamrudha.org/).

Table-7: Amylose & Amylopectin content of millets.

Cereal grain	Amylose (%)	Amylopectin (%)
Proso millet	28.2	71.8
Foxtail millet	17.5	82.5
Kodo millet	24.0	76.0
Finger millet	16.0	84.0
Sorghum	24.0	76.0
Bajra	21.1	78.9
Short Grain Rice	12-19	88-81
Wheat	25.0	75.0

(Source: *MILLET in your Meals*, http://www.sahajasamrudha.org/).

Declining small millet cultivation:

Even though millets have extraordinary nutritional qualities of grains and capacities of millet farming systems, the acreage under millet production has been shrinking over the last five decades. The period between 1961 and 2009 witnessed significant decrease in cultivated area under millets, more so in case of small millets (80% for small millets other than finger millet, 46% for finger millet). The area under all small millets other than finger millet has declined drastically in all states and the total production of small millets has declined by 76% and the productivity has remained more or less stagnant in the last two decades.

Small millets and nutritional security:

As it becomes clear from the data presented small millets are superior in one or more of the nutritional components compared to most widely consumed cereals, hence contribute towards balanced diet and can ensure nutritional security more easily through regular consumption along with keeping the environment safe as they are low input crops mostly adapted to marginal lands. Declining small millets cultivation has resulted in reduced availability of these nutritious grains to needy population and also the traditional consumers have gradually switched over to more easily available fine cereals due to government policies. This trendis disturbing which needs focus by the agricultural experts and policy makers. Immediate action on policy-guidelines, market support, value addition and promotional activity are necessary for checking the further decline in cultivation and also in consumption, improving productivity and enhancing demand should be the twin approaches that are to be followed simultaneously, which will ultimately help in promoting the production and consumption of millets. Developing health foods with their proper commercialization need special focus to promote the millets among the urban elite, which would lead to reduction in life-style related disorders.

Small millets consist of a about a dozen distinct species of small-seeded grasses that are grown for grain, each with their own unique traits and value. The most economically significant of these at present is finger millet, but the other small millets are each in their own way important to the farmers who grow them, and are also potentially important to breeders of other cereals as sources of traits that can improve the resilience and nutritional value of those more widely grown crops. Small millets provide staple food grain for millions of poor smallholders and households in the developing world's harsh, most food insecure regions, such as the Sahel in Africa and in South Asia's semi-arid zone, with feed grain and fodder for the livestock. By default small millets are extraordinarily tolerant to drought and other abiotic stresses, which makes them “climate smart” and a good source for genetic traits that can strengthen the resilience of other crops in the face of climate change. As climate progresses to hotter and drier, small millets and other dryland cereals will become increasingly well suited for production in areas, where other crops are now grown comfortably. Millets in general provide many essential vitamins and micronutrients that can bolster nutrition for those living in dryland areas, particularly women and children, where small millets are especially rich in iron, zinc and calcium, and have other dietary qualities that can help stave off anemia, celiac disease, and diabetes. The millets with exceptionally high nutritional value – coupled with the impressive hardiness against climate change makes them an important food security crops, for humans as well as for livestock.

Minor millets can fight against lifestyle disorders and malnutrition

Diwakar Singh*, Udit M. Nakarani and Kiran P. Suthar

Minor millets are small grain cereals which are grown on marginal land with minimum inputs. They contribute towards food and nutritional security and are often considered as nutri-cereals because they provides important nutrients for normal functioning of human body. It is grown under rain fed condition and important for sustainable agriculture. Minor millets are also known as famine crops and orphan crops. Minor millets are drought tolerant crops. Looking the nutritional significance of millets the Government of India had declared the year 2018, as "National Year of Millets" and designated "Millets" as "Nutri-Cereals".

Food play important role in health as well as diseases. With current increase in lifestyle disorders around the world, it is important to promote healthy nutrition in all age groups. There should be an improvement in eating habit not for individual but for whole population. Nutrition is double edged sword as both over and under nutrition is harmful to health. Under nutrition is particularly harmful to infants and over nutrition in adulthood but after-years both forms are likely to affect all age groups. Some important under nutrition related diseases, like anemia is caused by insufficient intake of iron, osteoporosis is caused due to insufficient intake of calcium and several physiological disorders are caused because of inadequate intake of vitamins, etc. On the other hand over eating and lack of physical activity lead to obesity and obesity related health problems.

Consequences of malnutrition on human health:

Many developing countries are facing double burden of malnutrition, with hidden hunger on one side and obesity on the other. Approximately 1.9 billion adults are overweight or obese, while 462 million are underweight. Approximately 52 million children under five years of age are malnutritioned, 17 million are severely malnutritioned and 155 million are stunted, while 41 million are overweight or obese. Around 45% of global deaths among children under five years of age are linked to under nutrition (WHO, 2018).

In India, there is large-scale prevalence of stunted growth among children and anemia among pregnant women. In India 20 per cent of children less than five years of age suffer from malnutrition related disorders due to acute under nutrition. Forty three per cent of Indian children less than five years are underweight and 48 per cent (*i.e.* 61 million children) are stunted due to chronic under nutrition. India accounts for more than three out of every 10 stunted children in the world also has the highest number of low birth weight babies per year at an estimate of 7.4 million and around 70 per cent children in the age of 6 - 59 months are anemic. Children of mothers who are severely anemic are seven times as likely to be severely anemic as children of mothers who are not anemic (UNICEF 2018).

Lifestyle disorders:

Lifestyle disorders are increasing due to busy, sedative and less physical activities in the population. Major lifestyle disorders are diabetes (usually type II), hypertension, obesity, osteoporosis, chronic obstructive pulmonary diseases, cancer, chronic liver disease, alzheimer's disease, arthritis, asthma, metabolic syndrome and stroke. At global level 63% deaths are reported due to lifestyle disorders of which 80% of such deaths are reported in low and middle income countries like India. More than 9 million of such deaths happen before the age of 60. Globally these lifestyle disorders affect both men and women. In India 13% women and 9% men are overweight or obese. Obesity increases the chance of other lifestyle disorders. Cardiovascular diseases and diabetes will more than double and cancers will rise by 25% in the coming few years. Most of the people with diabetes are between 40 and 59 years. The most disturbing trend is the shift in age of onset of diabetes to a younger age in the recent years. The studies also reported three-fold higher mortality in diabetes compared to non-diabetic. With an estimate 75% of working women likely to suffer from depression or general anxiety disorder, compared to women with lesser levels of psychological demand at work.

Overeating and lack of physical activity results in obesity that is harmful for human health. Obesity is fast increasing across rural and urban areas. Obesity increases the risk of non-communicable diseases with increase in BMI and lead to several diseases like cardiovascular, diabetes, musculoskeletal disorders

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(especially osteoarthritis – a highly disabling degenerative disease of the joints) and some cancers (including endometrial, breast, ovarian, prostate, liver, gallbladder, kidney and colon). Chronic and non-communicable diseases are on the rise for example, the prevalence of type-II diabetes mellitus and impaired glucose tolerance are affecting, at an alarming rate, both rural (2.4%) and urban (11.6%) populations (WHO 2018). Increasing research and epidemiological evidence link the lack of dietary diversity to these health issues. Most health risk occurs due to malnutrition of vital nutrients. Therefore, everyone is conscious of their diet and so are the food product development terms around the world striving to provide missing pieces of to health puzzle. Nutrition is core of the diet of people, so there is need to go for nutritious food rather than bulk food.

Minor millets can fight lifestyle disorders and malnutrition:

Six minor millets like finger millet (*Ragi*), kodo millet, barnyard millet, little millet, proso millet, foxtail millet are widely grown. Minor millet grains are nutritionally comparable and even superior to major cereals with respect to protein, energy, minerals, nutraceuticals, phytochemicals, dietary fiber and vitamins therefore also called as nutri-cereals. These crops have substantive potential in broadening the dietary diversity, food security and nutritional security. Comparative nutritional profile of minor millets with rice and wheat is given in the table 1:

Table 1: Comparative nutritional profile of minor millets with rice and wheat (per 100 g)

Grain	Carbohydrate (g)	Protein (g)	Fat (g)	Dietary fiber (g)	Energy (Kcal)	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	B1 (mg)	B2 (mg)	B3 (mg)	Folate (µg)
Finger millet	66.8	07.2	1.92	11.2	320	364	210	146	2.5	4.6	0.37	0.17	1.3	34.7
Kodo millet	66.2	08.9	2.55	06.4	331	15.3	101	122	1.6	2.3	0.29	0.20	1.5	39.5
Proso millet*	70.4	12.5	1.10	-	341	14.0	206	153	1.4	0.8	0.41	0.28	4.5	-
Foxtail millet*	60.1	12.3	4.3	-	331	31.0	188	81	2.4	2.8	0.59	0.11	3.2	15.0
Little millet	65.5	10.1	3.89	7.7	346	16.1	130	91	1.8	1.2	0.26	0.05	1.3	36.2
Barnyard millet*	65.5	6.2	2.2	-	307	20	280	82	3.0	5.0	0.33	0.10	4.2	-
Wheat flour	64.7	10.6	1.47	11.2	321	39.4	315	125	2.8	3.9	0.46	0.15	2.7	30.1
Rice	78.2	7.9	0.52	2.8	356	7.5	96	19	1.2	0.6	0.05	0.05	1.7	9.32

(Source: Dayakar *et al*. 2017)

Minor millets are rich in methionine (an essential amino acid that improves protein quality) and provides 8-10 times more calcium than wheat or rice. Millet carbohydrates are reported to have the unique property of slower digestibility that is favorable for diabetic patients. The excellent malting qualities have added to the uniqueness of the grain in expanding its utility range in food processing and value addition. The millet crops may be grown in a wide range of environments and growing conditions from southern Karnataka state in India, the foothills of the Himalayas in Nepal and throughout the middle-elevated areas of Eastern and Southern Africa (ICRISAT, 2012).

Nutritional potential of minor millets in terms of protein, carbohydrate and energy values are comparable to the popular cereals like wheat and rice. Minor millet contains about 7.7-12.5% protein, 1.5–5.2% fat, 55–72.6% carbohydrates, 2–7% dietary fiber and 2.5–3.5% minerals. Finger millet contains 350 mg/100g calcium that is highest among all minor millets and approximately 10 times higher than rice and wheat. Calcium is a vital mineral and human body uses it to build strong bones and teeth. Calcium is also needed for heart and other muscles to function properly. Due to calcium deficiency there will be increased risk of developing disorders like, osteoporosis, osteopenia and hypocalcemia. Children who do not get enough calcium may not grow to their full potential height as adults. By inclusion of finger millet in human diet the calcium deficiency problem may be alleviated. Pearl millet contains highest iron content among all minor millets i.e. 11 mg/100g and it is around seven times more than rice and three times more than wheat. Iron deficiency causes anemia that lead to a decreased level of hemoglobin in red blood cells (RBCs). Hemoglobin is the protein in RBCs that is responsible for carrying oxygen to tissues. Iron deficiency anemia is the most common type of anaemia, and it occurs when body doesn't have enough of the mineral iron. Human body needs iron to make hemoglobin, when there is not enough iron in the blood stream, the rest of human body can not get the amount of oxygen it needs. Prevalence of anemia is more in infants and pregnant women. Inclusion of pearl millet in regular diet may alleviate iron deficiency condition in human. Minor millets also contain bio active compounds like phytates, polyphenols, tannins, trypsin inhibitory factors, which are considered as "anti-nutrients" due to their metal chelating and enzyme inhibition activities but nowadays they are termed as neutraceuticals. It has been established that these anti-nutrients reduce the risk for different types of cancer like colon cancer, breast cancer, esophageal cancer, etc. The seed coat of the minor millets is an edible component of the kernel and is a rich source of phytochemicals, such as dietary fiber and polyphenols. It is now established that phytates, polyphenols and tannins can contribute to antioxidant activity of the minor millets based foods. This is an important factor in improvement of human health, delay in aging and prevention in metabolic disorders. Minor millets are also rich in vitamin B complex, especially vitamin B_1 (thiamin), vitamin B_2 (riboflavin) and vitamin B_3 (niacin). Vitamin B_1 deficiency causes peripheral nerve damage (beriberi) or central nervous system lesions (Wernicke-Korsakoff syndrome). Vitamin B_2 deficiency causes lesions in corner of mouth, lips and tongue and also seborrheic dermatitis. Vitamin B_3 deficiency causes pellagra (photosensitive dermatitis) and depressive psychosis. By addition of minor millets in regular diet the deficiency disease caused due to vitamin B_1, B_2 and B_3 may be lessening at a great extent. Minor millets are also significantly rich in resistant starch and soluble and insoluble dietary fibers. Resistant starch decreases postprandial glycemic and insulinemic responses, lower plasma cholesterol and triglyceride concentrations, improve whole body insulin sensitivity, increase satiety and reduce fat storage. These properties make resistant starch an attractive dietary target for the prevention of diseases associated with dyslipidemia and insulin resistance as well as the development of weight loss diets and dietary therapies for the treatment of type II diabetes and coronary heart disease. Dietary fiber which is indigestible in human small intestine on the other hand digested completely or partially fermented in the large intestine, are available in two forms i.e. water-soluble and water insoluble organic compounds. Dietary fiber can be separated into many different fractions, these fractions include arabinoxylan, inulin, pectin, bran, cellulose, β-glucan and resistant starch. Dietary fiber components organize functions of large intestine and have important physiological effects on glucose, lipid metabolism and mineral bioavailability. Dietary fibers are known to be protective effect against certain gastrointestinal diseases, constipation, hemorrhoids, colon cancer, gastroesophageal reflux disease, duodenal ulcer, diverticulitis, obesity, diabetes, stroke, hypertension and cardiovascular diseases.

Minor millet based food industry:

The minor millet market can be segmented based on product into Porridges, Steam cooked products, Breads, Beverages, etc. Porridge and steam cooked products have been some of the major traditionally cooked products from minor millets. These are primarily consumed in different parts of India and Africa. Porridge is the commonly prepared food from minor millets. In India, fermented minor millet flour is steam cooked to make kudumu. Fermented minor millet based products, which are traditionally prepared in India include idli, dosa, massa, injera, kisra, and galettes.

Now a days in food market number of ready to cook (RTC) millet based food products are available like ragi malt, organic baby food, millet pulao, millet dosa mix, barnyard and foxtail millet dosa and idli, proso millet upma, ragi vermicelli, kodo millet, little millet kheer, etc. Ready to eat (RTE) millet based food products are also available, like nutrimix chocolate, multi millet cookies, cake, khichadi, flakes, muesli, muffins, bread, chikki, crispy, lassi, ice cream, ragi balls, etc.

Based on geography, the global minor millets market can be segregated into North America, Europe, Asia Pacific, Latin America, Middle East and Africa. All types of minor millets are generally cultivated in Africa, India and China. In Asia, India is the key producer of minor millets, which are primarily grown in north-western and southern-east parts of the country. Nepal and Bhutan are also major minor millet producing countries in Asia.

Conclusion:

Lifestyle disorders, malnutrition and chronic diseases are increasing at alarming rate in the Indian population. Diet play important role in controlling such disorders and inclusion of minor millet based food products promise to prevent deterioration of human health by bio-availability of vital nutrients, lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, diabetes, decreasing tumor cases, etc. Further minor millet based food also fights with the mineral and vitamin deficiency, hence alleviate hidden hunger. In the recent decade due to nutritional significance of minor millets in diet and health, several millet based food industries have evolved and marketing RTC & RTE millet products. Minor millets are considered as nutri-cereals, hence can fight against lifestyle disorder, chronic diseases and malnutrition.

Enhancing shelf life and value addition in pearl millet

Supriya Ambawat[1], C Tara Satyavathi[1], Subaran Singh[2], Suman[3] and Shobhit[4]

Abstract : Pearl millet (*Pennisetum glaucum* L.) is the most widely grown staple food of the majority of poor and small land holders in Asia and Africa. It has high nutrition value and rightly termed as nutricereal as it is rich in protein, dietary fibre, essential fatty acids, vitamins and minerals. In this context, it is important to raise the awareness on its nutritional value and reorient the efforts to improve its yield and quality. Though it is nutritionally very rich, the full potential of pearl millet flour is limited due to problem of rancidity and off odour during storage. High fat content along with highly active lipases causes hydrolysis of fat into fatty acids. It contains 75% unsaturated fatty acids and the presence of relatively high level of unsaturated fatty acid along with several enzymes like lipases, peroxidases, polyphenolics causes rapid deterioration in the pearl millet flour leading to reduction in its shelf life. Thus, biochemical interventions and efficient processing technologies are required to enhance and improve the pearl millet storage quality and increase the demand and consumption of this nutricereal and its value added products.

Introduction

Nutritional quality of food is a major key player for health and development and maximization of human genetic potential. Hence, dietary quality should be taken into consideration and is very important to meet out hidden hunger and malnutrition. It contains more nutrients than rice or wheat and is rich in essential compounds like protein, fibre, phosphorous, magnesium and iron. Due to its rich composition of minerals and proteins, it has many health benefits like reduction in blood pressure, diabetes, thyroid, cardiovascular and celiac diseases and rightly termed as nutri-cereal (Table 1). Pearl millet is a good source of energy, carbohydrate, fat, ash, dietary fibres, iron and zinc. It is high in fibre (1.2g/100g) and in α-amylase activity when compared with other grains. Pearl millet is gluten free and retains its alkaline properties after being cooked which is ideal for gluten allergic people. It is a rich source of vitamins like thiamine, riboflavin and niacin and minerals(2.3mg/100g) like potassium, phosphorous, magnesium, iron, zinc,

Table 1. Possible health benefits of pearl millet on various diet related deficiencies/ disorders

Positive factor in pearl millet	Possible benefit	Disease/problem
High iron and Zinc Content	May help in increasing Hb	Anemia
High fiber	May help in dealing with constipation	Constipation
Antioxidant property, high flavonoids	Anti cancer property, inhibit tumor development	Cancer
Gluten free	Anti allergic	Celiac
Low glycemic index	Help in dealing with diabetes	Diabetes
Lactic acid bacteria	Probiotic treatment	Diarrhea
Flavonoids, phenolics, omega 3 fatty acids	Inhibits DNA scission, LDL cholosterol, liposome oxidation and proliferation of adenocarcinoma cells	NCDs

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copper and manganese. Pearl millet is rich in fat content (5mg/100g) with better fat digestibility (Table 2). It is rich source of unsaturated fatty acids (75%). It has high proportions of slowly digestible starch (SDS) and resistant starch (RS) which contribute to low glycemic index (GI) and is the need of the transforming diets, food habits and the food industry(Himanshu *et al*.,2018)

Pearl millet (*Pennisetum glaucum* L.) is the most widely grown millet and is a staple food for more than 90 million people living in drier parts of Asia and Africa. India is the largest producer of pearl millet both in terms of area (9.5 million hectares) and production (9.7 million tons). It occupies 7.4 million ha with an average production of 9.13 million tonnes and productivity of 1237 kg/ha during 2017-18 (Directorate of Millets Development, 2019).It is dual purpose crop and is well adapted to grow under most adverse agro-climatic condition characterized by drought, low soil fertility and high temperature.

Table 2. Nutritional constituents in pearl millet grain

Nutritional value per 100 g	
Energy	361 kcal
Carbohydrates	67.5 g
Dietary fiber	6.0 g
Fat	8.4 g
Saturated Fat	1.4 g
Monounsaturated Fat	1.5 g
Polyunsaturated Fat	4.3 g
Fatty Acids	236 mg
Saturated Fat Omega-3	1.4 g
Omega-6 Fatty Acids	4 g
Protein	11.6 g
Minerals	2.3 g
Iron	16.9 mg
Zinc	3.4 mg
Calcium	38 mg
Magnesium	228 mg
Phosphorus	570 mg
Potassium	390 mg
Riboflavin	580 mcg
Niacin	9.4 mg
Thiamine	842 mcg

Source: www.ijarie.com

Though it is nutritionally very rich, the full potential of pearl millet flour is limited due to problem of rancidity and off odour during storage. It contains 74% unsaturated fatty acids like oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) and 26% saturated fatty acid such as palmitic (C16:0) and stearic acid (C18:0) (Satyavathi*et al*., 2017). It has high level of fat rich in ν-3 fatty acid and has high lipase activity which results in rapid release of short chain fatty acids from long unsaturated fatty acids developing off odour and limits the shelf life of millet flour. Pearl millet is also reported to contain oxidative enzyme such as peroxidase and enzymatic browning catalysed by enzyme such as polyphenol oxidase (PPO), both of which play important role in pearl millet flour quality deterioration. Due to above reason, pearl millet flour can only be stored for short period of span and it quickly get rancid and off odour. Thus, biochemical interventions and development of efficient processing technologies are the need of the hour to mitigate the issue of rancidity and improve the pearl millet flour keeping quality which can ultimately reduce drudgery of women and further promote the commercialization and usage of this Nutricereal.

Rancidity and its effects

Rancidity is derived from "rancidus" the Latin word for stinking. The term 'rancidity' is used for unpleasant odours and flavours in foods resulting from degradation in the fat content. Thus, a biochemical reaction between fats and oxygen *i.e.* oxidation of fats leads to rancidity where long-chain fatty acids are degraded and short-chain compounds are formed. Hydrolysis of lipids, oxidative changes in unsaturated fatty acids, enzymatic changes in C-glycosyl flavones and presence of meal phenolics and their enzymatic degradation and high peroxide activity are some of the different factors responsible for rancidity in pearl millet. After milling of pearl millet grain enzymes like lipase, peroxidase, polyphenol oxidases, phenolics and C-glycosyl flavones get mixed with flour and fasten the degradation of fatty acids.

Enzyme lipase is found in the pericarp and shows relatively higher activity in pearl millet as compared to other cereal grains leading to the development of rancidity within a few days in pearl millet flour. Rancidity and off odour during storage of flour and its products reduces its marketability thus making it less profitable. Further, pearl millet flour can't be stored for long periods which lead to drudgery of women in houses as the women in villages hand pound the grain daily according to the need. Hence, rancidity delimits its use in commercial products. The problem of rancidity also constraints the commercialization of pearl millet flour in the form of packaged shelf-stable pearl millet flour or use of pearl millet flour as an ingredient in the food processing industry.

Strategies to mitigate rancidity

The issue of rancidity can be addressed using various pre-processing and post processing treatments such as decortication or pearling of grain, which involves removal of outer fat layer; defatting of flour, use of antioxidants to reduce triglycerol oxidation, blanching, enzyme inactivation, malting, fermentation, storage in different packaging material, use of desiccant and storage at low temperature. Hence, research needs to be carried out to understand the variability in the rancidity profile existing among lines in pearl millet germplasm collections, identify lines having low susceptibility to rancidity and explore the preprocessing, processing and post-processing options of using these low rancidity profile lines to obtain shelf-stable pearl millet flour. Well equipped processing units with primary and secondary processing machinery including equipments for destoning, sorting and grading, dehulling, roasting, pulverizing, shifting, flaking and packaging can also help upto great extent in this direction.

Food processing techniques

Several food processing techniques are available which are used to enhance nutritional quality, improve the digestibility and bioavailability of food nutrients by reducing anti-nutrients. Some of the processing techniques such as decortication, milling, soaking, cooking, germination, fermentation, malting, popping etc. are mentioned below:

Milling: Physical appearance and functional properties of grains are improved by wetting the grains, conditioning and removing the bran by an abrasive device in the mill.

Puffing/Popping: During popping sand is used as heat transfer media with high temperature short time resulting into starch gelatinization and the endosperm bursts open giving highly desirable flavor and aroma. At commercial scale, it may be used as ready-to-eat food promoting utilization of millet grains. Puffed products exhibit low bulk density with distinct flavour and pleasing texture. Roasted puffed grains are used as snack after spicing whereas the powdered product can be consumed in combination with other flours and can be used to make different products like sweet and savoury products.

Flaking: After partial roasting of somewhat premature harvested grains, they are flattened, dried, stored and usually deep fat fried before consumption as a snack. The dried millet flakes are powdered and used as a weaning food.

Malting: Malting yields a maximum fall in the viscosity of grains that enhances the nutritional benefit, while the process of malting is used often in the formulation of low cost weaning foods.

Fermentation: Millet flour can be used to prepare fermented gruels, dosas, idlies etc. The gruel can be cooked and fermented or subjected to heat treatments. This technique can be used to make many varieties of food products with different flavors and texture thus improving the nutritional properties of raw food significantly. By fermentation level of antinutrients is decreased and *in vitro* digestibility, protein availability is increased along with some considerable changes in chemical composition of food material. It also increases nutrient value like moisture, ash, fibre, protein and fat and significantly reduces mineral contents.

Germination

Germination of pearl millet millet can decrease level of anti-nutrients such as phytic acid, tannins and polyphenols and increases the in vitro protein and starch digestibility, beta-amylase activity, *in vitro* extractability and bio-accessibility of minerals such as calcium, iron and zinc.

Soaking

Soaking of grains is popular and general food processing technique which reduces antinutritional compounds like phytic acid and phytase activity to improve bioavailability of minerals.

Value addition and value added food products

To create value of any product, it is transformed by adding some additional components at different stages. Thus, value addition is not only confined to processing of the raw material/ product but it also involves physical changes in the product via different factors. ITC, Reliance, Food World etc. are some of the private brands involved into food retail chain and expanding their business due to increase in income and demand in major urban centres. Urban consumers are willing to pay higher prices for high quality with known levels of food safety. Further, there are opportunities for improved efficiency in the supply chain through sorting, grading and packing in different sizes. Several pearl millet based traditional products, bakery products, extruded products, health products like porridge, khichri, ladoo, biscuits, cakes, dosas, idliespasta, noodles pizzas, burgers etc. are available in the market and their demand is increasing day by day due to their health benefits. These can be classified into 9 major food categories like thick porridge, thin porridge, steam cooked products, fermented breads, unfermented breads, boiled rice-like products, alcoholic beverages, nonalcoholic beverages and snacks (Figure 1). The simplest and the most common traditional food made from pearl millet are thin porridge (gruel); thick porridge (fermented and unfermented); flat and unfermented bread such as chapatti. Flat, unleavened bread prepared from pearl millet flour enriched with soy flour has been reported to have high protein efficiency ratio, minimal thickness, puffing, and uniform color and texture. The enhanced overall acceptability of chapati prepared from bleached or heattreated grain was higher in comparison to that prepared from untreated grains.

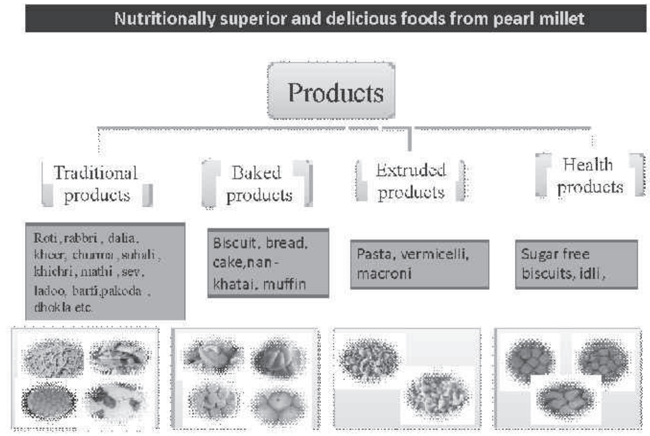

Figure 1. Various value added products prepared from pearl millet

Conclusion

The main constraint in enhancing the demand for Pearl millet has been the problem of rancidity in pearl millet flour as well as in value added products prepared using pearl millet flour. Thus, as discussed in the earlier sections appropriate research and development, leveraging on the past and ongoing research activities, towards tackling the issue of rancidity in pearl millet flour is the most important intervention required for ensuring a sustainable demand for pearl millet. In addition, focus on creating demand pull for pearl millet through an integrated value chain approach by linking the farmers to the markets need to be undertaken and equipments must be available for directly processing the farmers produce as per market demand which can motivate the farmers to grow pearl millet. Thus, holistic approach with research on appropriate pre- and post-harvest strategies, processing strategies and marketing strategies with the intervention of government policies can play great role to promote the consumption of this wonder millet. To bring millets into mainstream for exploiting the nutritional rich properties and promoting their cultivation, Govt. of India has declared Year 2018 as the "Year of Millets" and included it in Public distribution system and renamed it as *nutri-cereal* (Gazette of India, No. 133 dtd 13th April, 2018).

Improved varieties and production technologies for minor millets

Dilip Panwar, Manoj Kumar Saini, Sanjay H.B., V. Anjula Krishna and P. Supriya

Millets are group of small grained cereal food crops which are hardy and grow well in dry zones as rainfed crops under marginal condition of soil fertility and moisture. The name millet is derived from the word *mil or thousand* it means a large number of grains can be produced from single seed. The Hindi word kadann has come from Sanskrit word kadannam which refers to food grains of poor. Most of millets are relative of India and provide nutrients required for normal functioning of human body and hence they are also referred as nutri-cereal. Millets can be grown with low level of input and withstand sever abiotic and biotic stress. Millets are adapted to wide range of ecological conditions and are often grown on skeletal soils and mature quickly with in 3 to 4 months. Among these crops finger millet is the most important food grains widely grown in India from the semi-arid planes to the foothills of the Himalayas after an elevation of 3500 MSL. Based on size of the grains of millet are classified into major millets and minor millets and following some are the minor millets grown in India. (Table 1). The production trends, nutritional profile and varieties are given in Table 2, 3 and 4).

Table 1: List of minor millets grown in India

Sl.No	Common name	Botanical name
1	Foxtail millet (kangni, Italian millet)	*Setaria italica*
2	Finger millet (Ragi,Mandua)	*Eleusine coracana*
3	Kodo millet (Varagu,Bastard)	*Paspalum scrobiuculatum*
4	Little millet (Blue panic)	*Panicum sumatrense*
5	Barnyard millet (Sawan,jhangora)	*Echinochloa esculenta*
6	Proso millet (cheena)	*Panicum miliacum*

Importance of minor millets

Minor millets are good for consumers they can help to overcome some of the biggest nutrition and health problems, their water use efficiency is very heigh and have ability to tolerate drought. And also they are highly responsive to high dosage of fertilizers so that their yield can be increased up to 3 folds. As it is a C4 plant and have high water use efficiency and having the ability to sequest the carbon and also highly responsive to input management.

Nutritional importance

Millets are abundant in the nutritional content like proteins, carbohydrates, fats, crude fiber, minerals matters, calcium, phosphorus and iron as compared to the other coarse grain cereals therefore millets are recommended for well-being of infants, lactating mothers and elders. It contains slow releasing glucose *i.e.*, low in glycemic index this is very much important in fighting the global problem of diabetes. Its fibre content also helps to prevent constipation. Millets are good for people who are gluten intolerant. Magnesium is micronutrient used for bone mineralization, teeth maintenance building up of proteins regular use of whole grain cereals and their products can protect against diseases like diabetes mellitus, gastrointestinal tract diseases, cardiovascular risk.kodo millet is rich in vitamin B especially niacin, pyridoxine and folic acid and calcium, potassium, iron, magnesium and zinc. And also rich in fibre and low in fat content. It contains high amount of lecithin and its it is an excellent for strengthening the nervous system that contain highest amount of protein (12.5%) barnyard millet grain have gama amino butyric acid (GABA) and beta glucan used as antioxidant and lowering the blood liquid level. Sprouting millets grains are used as feeding food for infant as early digest food for the elders and infants.

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Agronomic practices

Millets are most suitable cereals in many marginal soil environment. These food crops are special and climate resilient in nature and require less water to grow *i.e.*, about 300 mm of rainfall is sufficient to mature rapidly. Millets are one of the most farmer friendly crop and often considered as lazy farmers crop as if it does not requires deep care and least input is sufficient. Once after broadcasting with 2-3 life saving rainfall can protect the crop and farmer can expect to repay good harvest. In minor millets lines sowing is practiced, it can be intercropped with any other pulses. Most of millets are short duration crop and drought tolerance fit in contingency crop planning to mitigate the drought. Drought resistance of millet can be enhanced by seed hardening process. seed hardening can be done by soaking seeds in 2% potassium chloride solution for 12 hours followed by sun drying for 15 hours.

When coming to nutrient requirement, about 25:15:15 ratios of NPK are sufficient here full dosage of phosphorus and potassium are applied at the time of sowing and half dose of nitrogen at the time of sowing and remaining half dosage is at 30 to 35 DAS as top dressing. Millet can complete its crop duration in 95-130 days. After maturation that can be harvested by reeping followed by threshing. Due to the presence of husk and brans in the seeds limits the processing of millets, this can be removed by hand pounding and mechanically by using rubber roll sheller and abrasive grain polisher. At the time of harvesting and storage the moisture percentage of the seed should be at 20% and 14% respectively.

Benefits of millets in comparison to the commercial crops

Millet cultivation provides more economic stability to farmers than commercial crops. There is a belief that commercial crops benefits the farmers monetarily and farmers who committed suicide due to drought conditions were the one who went for commercial crop which cannot tolerate drought condition and who did not prefer the traditional crops like millets. One of the good example is BT Cotton which yields 5-6 quintal and gross income was 10000 to 12000 rupees per acre and net income is around 5,000 after deducing the expenses in case of millets gross yield is 5-6 quintal per acre then income per acre was between 16 to18 thousand rupees and farmers net income would be around rupees 13,000 to 15000 per acre after deducing the expenses. The main benefit of growing millets is our low expenses, we spent for practices in the field. These crops give more benefit to farmers as these can tolerate changes in the climate than commercial crops and give good net income to the farmers. Now a days as health consciousness is increasing among the people

Table 2: Contribution of India to global millet production during 2016

Sl.No	Crop	Area (1000 ha)	Production (1000 tonnes)	Productivity (kg/ha)
1.	Foxtail millet	72.6	50.2	691
2.	Finger millet	1138.3	1822	1601
3.	Kodo millet	200	84.2	419
4.	Little millet	255.5	119.9	469
5.	Barnyard millet	146	151	1034
6.	Proso millet	31	20	645
	TOTAL	1843.4	2247.3	4859

Source :- IIMR estimates based on FAO / DES –GOI data

Table 3 : Nutritional composition of millets

Grain	Carbo-hydrateses (g)	Protiens (g)	Fat (g)	Energy (K.cal)	Fiber (g)	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	Vit B2 (mg)	Vit B1 (mg)
Foxtail millet	60.1	12.3	4.3	331	-	31	188	81	2.4	2.8	0.11	0.59
Finger millet	66.8	7.2	1.92	320	11.2	364	210	146	2.5	4.6	0.17	0.37
Kodo millet	66.2	8.9	2.55	331	6.4	15.3	101	122	1.6	2.3	0.20	0.29
Little millet	65.5	10.1	3.89	346	7.7	16.1	130	91	1.8	1.2	0.05	0.26
Barnyard millet	65.5	6.2	2.20	307	-	20	280	82	3	5	0.01	0.33
Proso millet	70.4	12.5	1.10	341	-	14	206	153	1.4	0.8	0.28	0.41

Source :- IIMR

Table 4: Varieties of minor millets grown in India

Crop	Varieties	Year of release	Area of adaptation
Finger millet	DHFM 78-3	2018	Karnataka
	Chhattisgarh ragi	2018	Chhattisgarh
	VL 379	2017	Uttarakhand, Bihar, Jharkhand, MP, NE States of India
	GNN7	2017	Gujarat
	CO 15	2017	Tamilnadu
Foxtail millet	DHFt109-3	2018	Karnataka
	RAU (Rajendra Kauni 1-2)	2017	Irrigated & Upland of Bihar
	Si A 3088	2012	AP,Bihar,Gujarat,Karnataka
	Surya Nandi	2012	National
	HMT 100-1	2008	Karnataka
Kodo millet	Jawahar Kodo	2016	Rainfed area of MP
	RK390-25	2012	National
	TNAU 86	2012	National
	Chhattisgarh Kodo-2	2014	Chhattisgarh
	Indira Kodo-1	2012	Chattisgarh
Barnyard millet	CO-(KV)-2	2008	Tamilnadu
	DHBM93-3	2016	National
	DHBM 93-2	2016	National
	MDU-1	2018	Tamilnadu
Little millet	DHLM-36-3	2018	Karnataka
	GNV-3	2018	Gujarat
	DHLM-14-1	2017	TN,KA,Gujarat,MH,Orissa
	Jawaharkranti-4	2016	Rainfed ares of MP
	Pule-Ekadashi	2016	Maharastra
Proso millet	DHP2769	2018	Karnataka
	TNP-m-230	2017	National
	TNAU-202	2011	National
	PRC-1	2008	Uttarakhand hills
	Pratap cheena-1	2006	National

demand is increasing but production is not up to the mark to meet out the consumer needs so we need to encourage farmers to go for millets to reap benefits and to avoid farmer suicides in the country.

Swachh Bharat Abhiyan

स्वच्छ भारत

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