SOUVENIR

NATIONAL CONFERENCE

on

Production, Processing and Marketing of Millets: Issues & Solutions

March 1st - 2nd, 2023

Jointly organized by

Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, Madhya Pradesh

NABARD
National Bank for Agriculture and Rural Development, Bhopal

In Collaboration with

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP)

National Conference
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National Conference
on
Production, Processing and Marketing of Millets: Issues & Solutions
(1-2 March, 2023)

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Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, Madhya Pradesh, India

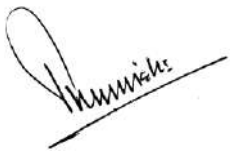
FOREWORD

Millets are designated as SHREE ANN on the occasion of International year of Millets-2023 in light of their nutritional values and suitability for climate resilience.

Food grain sufficiency has been attained through development of high yielding varieties of crops, assurance of input supplies and potential utilization of natural resources during post green revolution in the country. During the period major emphasis were on increasing food grain production to feed the people which led to ignorance towards the indigenous nutri-rich crops like millets. These are traditionally cultivated on marginal lands with least agri-inputs and having low productivity. Small-grained cereal grasses are collectively termed as 'Millets' and based on the grain size they are grouped in two categories viz. major millets (sorghum and pearl millet) and small millets (finger millet, little millet, kodo millet, foxtail millet, barnyard millet and proso millet). Recent past has witnessed the tremendously higher demand of millets at global levels owing to their high nutritive and medicinal values and resilience to climate change.

It is the right time to relook towards the promotion of millets cultivation through introduction of improved agro-technologies for productivity enhancement, value addition and marketing to improve farmer's livelihood. State of Madhya Pradesh has been ranked first in contribution of small millets towards national food basket. To accelerate the adoption of millet cultivation, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is organizing a National conference on **Production, Processing and Marketing of Millets: Issues and Solutions** during 1st & 2nd March 2023, on the occasion of International year of Millets-2023. I strongly believe that this conference will provide concrete recommendations for increasing area and production of millet crops and improving livelihood of millets grower through value addition and marketing of millets produce.

My heartiest congratulations to the organizers and best wishes for grand success of the conference.



(P.K. Mishra)
Vice Chancellor

24th February, 2023

Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, Madhya Pradesh, India

PREFACE

Different small-grained cereal grasses are collectively described as 'Millets'. Millets are one of the oldest cultivated foods known to humans. Based on the grain size, two main groups of millets are major millets and small millets and both have traditionally been the main components of the food basket of the poor people in India and traditionally been cultivated under rainfed farming system and are excellent source of protein, fiber, vitamins and minerals. India is the highest producer of Millets in the world and accounting for 20 % of global production and 80% of Asia's production. Madhya Pradesh covers 33.4% of small millets area of the country and contributes 26.6% of production. FAO has aimed to increase the awareness about millets in food security and nutrition during 2023. In-spite of these, cultivation of small millets in India has not getting required swiftness mainly due to lower productivity and consequently poor economic returns. Cultivation of millets had been mostly confined in tribal areas under rainfed conditions on marginal soils posing poor fertility and moisture supplying capacity that results in large yield gaps. Non-availability of quality seeds, processing unit and poor marketing are some key reasons for poor adaptation of millets cultivation. It is the potential time to exercise towards enhancing the area and productivity of millets through dissemination of improved agro-technologies for improving the livelihood of growers.

To accelerate the adoption of millets cultivation this two day's national conference on **Production, Processing and Marketing of Millets: Issues and Solutions"** is being organized at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

We express our gratitude towards Hon'ble Vice Chancellor JNKVV, Jabalpur, for his visionary approach, guidance and timely support for execution of this mega event. We further extend our gratitude to Government of Madhya Pradesh, NABARD, Mandi Board, PPV&FR Authorities, Govt. of India and GIZ for providing financial and technical support towards successfully organizing this National conference at JNKVV Jabalpur. We also thank over all the dignitaries, lead speakers and entire team of "MILLET CON-2023" for their valuable support.

Dr. G.K. Koutu
Director Research Services
Dr. D.P. Sharma
Director Extension Services
(Organizing Secretaries)

24th February, 2023

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LEAD PAPERS

THEME-I

"INTERVENTION FOR ENHANCING PRODUCTIVITY OF MILLETS"

PROBLEMS AND PROSPECTS OF QUALITY SEED PRODUCTION OF MILLETS FOR SUSTAINABLE LIVELIHOOD

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'Millet' is a collective name used to describe a number of different small-seeded annual cereals. Although millets do not derive from one plant species, they do share consistent common features. Millets are usually subdivided into 'large millets' (sorghum and pearl millet) and 'small millets' (finger-, barnyard-, little-, kodo-, foxtail-, proso- and brown-top millet). They are drought resistant crops and adapted to dryland agro-ecologies of the arid and semi-arid tropics, and are produced in regions characterized by low to moderate rainfall (200-600 mm) and high temperatures (42-46°C).Millets share certain common characteristics and their socio-economic relevance is highlighted below:

- Millets are recognized among the most ancient food grains - first plants domesticated for food. The earliest evidence of their cultivation found in Indus civilization dates back to 3,000 BC, making them an integral part of the culture and history of India. The references to millets can also be found in mythology, poetry, religious practices, ayurvedic recipes, and in numerous dishes, and hence, they are still intricately interwoven in the socio-cultural fabric of numerous regions of the country.
- Millets are C4 carbon sequestrating crops, which have greater potential to utilize atmospheric CO_2 in the accumulation of biomass per unit of water used and thus are recognized as crops with low carbon- and water-footprints. The short life cycle of millets (10–12 weeks) as compared to other major crops (20–24 weeks) also helps in stress mitigation. Because of these attributes, millets are considered climate smart crops.
- Millets have in-built tolerance to water stress and supra-optimal temperatures due to their morpho-physiological, molecular and biochemical characteristics that confer upon them better tolerance to environmental stresses than the major cereals. Thus, they possess good ability to adapt to marginal lands and thrive in dry regions under resource poor agro-climatic conditions like low soil fertility. Hence, they are sometimes called 'miracle grains' and designated as 'future super foods'.
- Millets are largely produced with low external inputs especially chemicals, these are considered as nature friendly. These crops are usually cultivated as dual-purpose crops providing both food grain for human consumption and straw for animals, contributing to economic efficiency in mixed farming systems.
- Numerous varieties of millets exist with differentiated cultivation and taste characteristics, including hybrids, improved varieties, and local ones. This especially

applies to local varieties which are predominantly conserved on-farm. Millets are frequently cultivated with other millet varieties, pulses, beans, oilseeds, etc. as part of the mixed farming system. The rich crop and varietal diversity of millet-based cropping systems foster and enrich agro-biodiversity of their ecosystems.

- Millets are highly nutritious, containing high amounts of proteins and fibre, B-complex vitamins including niacin, thiamine and riboflavin, the essential sulphur-containing amino acid methionine, lecithin, and vitamin E. They are rich in iron, magnesium, calcium and potassium. The seeds also contain phyto-nutrients, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reducing risk of cancer. Millets contain more dietary fibre and higher amylase inhibitory activity and thus millets-based foods are low in glycemic index. Life style diseases such as hyperglycemia, obesity, cardiovascular diseases, incidence of colon cancer, etc. are known to be reduced or well managed by adopting millet-based diet. Government of India has declared 10 millet crops as 'Nutri Cereals' for production, consumption and commerce which include three major millets i.e., pearl millet, sorghum and finger millet; five minor millets i.e. foxtail millet, proso millet, kodo millet, barnyard millet, little millet; and two pseudo millets i.e. kuttu (buckwheat) and amaranthus (vide F.No. 4-4/2017-NFSM (E) dated 10th April, 2018).

Thus, millets remain a staple crop for numerous households, providing them food, nutritional and livelihood security in particular, small and marginal farmers and inhabitants of rainfed areas, poor and malnourished population, especially in remote tribal areas. Further, it can help achieving the first three sustainable development goals of the United Nations i.e. reducing poverty, zero hunger and good health and well-being.

Millets are grown in 131 countries and comprise traditional food for 59 crore people in Asia & Africa. The global production of millets is 89.17 m t from an area of 74 m hac (FAO, 2020). India is the biggest producer of millets in the world, accounting for 80% of Asia's & 20% of global production (Table 1). In India, millets are cultivated in 21 states covering an area of 12.45 million hectares, producing 15.53 million tonnes with a yield of 1247 kg/ha (Table 2). Sorghum is the fourth most important food grain in India after rice, wheat, and maize in terms of area (4.83m ha) and production (4.31 mt). Bajra is contributing more than 50 per cent of the country's area under millets (7.05 m ha) with nearly equal percentage of production. It is interesting to note that, India is the topmost producer of Barnyard (99.9%), Finger (53.3%), Kodo (100%), Little millet (100%) and pearl millet (44.5%), producing about 12.46 million metric tonnes from an area of 8.87 million ha.

Table 1: Region wise area and production of millets (2019)

Region	Area (m ha)	Production (m ton)
Africa	48.9	42.3
Americas	5.3	19.3
Asia	16.2	21.5
Europe	0.8	2
Australia & New Zealand	0.6	1.2
India	**13.8**	**17.3**
World	**71.8**	**86.3**
Source: FAOStat, 2021		

Table 2: Area under cultivation, production, and yield of millets in India

Crop	Area (m ha)	Production (m t)	Yield (kg/ ha)
Sorghum(kharif)	1.76	1.58	967
Sorghum (rabi)	3.07	2.73	1002
Sorghum (Total)	4.83	4.31	989
Bajra	7.55	9.22	1374
Ragi	1.01	1.67	1747
Small millets	0.46	0.33	809
Total millets	13.83	15.53	1248
Source: Final Estimates-2021-22, Directorate of Economics & Statistics, DA&FW, GoI			

The production of millets in India has shown very interesting trends. A consistent increase in the production was observed between 1950-1990 (about 1.4 times), along with an increase of similar magnitude in the crop productivity, but a marginal decline (8%) in the acreage (Table 3). However, there had been a steady decline in the total millet cultivation during 1950-2020 and witnessed a drastic change after nineties, whereby production came down by 20% as the area declined by 54%, though the crop productivity exhibited 73% increase during 2010-20 in comparison to 1980-90.

Period	Area (m ha)	Production (m t)	Yield (kg/ ha)
1950-60	35.41	14.75	415
1960-70	37.30	17.15	460
1970-80	35.06	19.35	552
1980-90	32.58	20.60	633
1990-2000	25.26	19.64	778
2000-10	20.81	18.02	868
2010-20	15.01	16.42	1097
Source: NAAS, 2022			

Thus, a very high gain in productivity could not compensate for the reduced area and the overall production suffered a setback, associated with significant decrease in per capita availability.

In India, Rajasthan, Maharashtra and Karnataka are the topmost states in millets cultivation with a share of 35%, 23% and 14% to total millets area. Maharashtra and Karnataka have the maximum area under sorghum while Rajasthan, Gujarat, Uttar Pradesh and Maharashtra have more area under pearl millet. Ragi has the maximum area in Karnataka, Tamil Nadu and Uttarakhand. The biggest small millets producing state is Karnataka (56% of total production) followed distantly by Tamil Nadu (14.0%) and Uttarakhand (9.3%). Rest of the states together contribute about one-fifth of the total production.

Seed systems in millets: The data pertaining to indent and production of different seed classes of millet crops during 2021-22 is presented in Table 4.

Table 4: Indent and Production of different seed classes of millet crops during 2021-22

Crop	Breeder seed		Foundation seed		Certified seed		Truthfully labelled	
	Indent	Prod.	Indent	Prod.	Indent	Prod.	Indent	Prod.
Sorghum	356	364	870	644	12955	14254	226	375
Pearl Millet	3.06	23.13	60	61	0	0	36	32
Finger Millet	51.8	246	876	542	4387	3827	142	249
Little Millet	9.0	7.9	10	12	25	24	53	63
Kodo Millet	21.35	26.08	0	34	0	64	11	69
Foxtail Millet	0.2	2.0	59	32	55	57	511	545
Barnyard Millet	5.0	5.1	6	6	26	30	42	82
Browntop Millet	0	0	0	0	0	0	7	4
Italian Millet	0.85	0.85	0.0	0.0	0.0	0.0	6	2.6
Proso Millet	1.3	1.8	3	3	8	10	22	34
Grand Total	**449**	**677**	**1885**	**1334**	**17455**	**18266**	**1056**	**1456**

Sorghum seed system: Sorghum seed system is very unique in the country with contrasting situations and systems. Hybrids are the cultivar choice in kharif (rainy season) sorghum, and hybrid adoption by farmers in states like Maharashtra is up to 95%,though there are wide variations in adoption across the states in India. The public and private sector seed companies develop hybrids and rule the market. The seed requirement is predominantly met by the vibrant formal seed system, comprising of private sector seed companies and public sector seed agencies like National Seeds Corporation (NSC), State Seed Development Corporations in different states and Mahabeej in Maharashtra. In the case of post-rainy season sorghum cultivated on black soils under residual moisture conditions, open-pollinated varieties are the cultivar choice because of

stringent quality considerations, lack of appropriate hybrids, inadequate hybrid seed production, and supply chain. The availability of seed of high-yielding and improved cultivars is not a constraint in kharif sorghum, but the major issue in post-rainy season sorghum in India is that majority varieties are age old and still ruling the major area under cultivation. Most notable local varieties popular among the farmers include M 35-1 (Maldandi) and Dagadi grown by 80–90% of farmers in India. M 35-1, a landrace selection from Maldandi, being cultivated traditionally by the farmers in these areas for several decades, was selected in 1938, nearly 75 years ago, and is still dominating the post-rainy season tracts (Maharashtra, Karnataka and Andhra Pradesh) in India.

Pearl millet seed system: Pearl millet seed system in India is dominated by formal seed system, withmore than 90% seed share accountedby private seed companies and mainly comprising of hybrids. However, the role of public sector is minimum. The low-income farmers, located mostly in water-scarce areas such as western Rajasthan and largely rain-dependent grow open pollinated varieties (OPVs) in the rainy season. Certain sections also have strong taste preference for OPV seed use. About 80% farmers purchase and re-use OPV seeds, as hybrids are unsuitable in water-scarce regions. Nevertheless, 20% farmers still use hybrids decision drivers.

Small millet seed system: Small millet seed system is mainly dominated by informal sector (>90%). In India, among millet crops, the seed replacement rate (SRR) is highest inpearl millet (60%) followed by sorghum (30%) and small millets (25–30%).

- The millet crops are characterized by lower crop productivity and yield instability, associated with rainfed millets production the lower shelf life of processed grain and the negative social status of millets as a poor man's crop. It was observed that the acreage of millets decreased due to area expansion under irrigation and consequent area shift towards wheat, rice and maize in the Post-Green Revolution era. The overall fall in demand is often attributed to factors like changing food habits, growing urbanization, increased incomes, competition from other crops, the time-consuming and back breaking dehulling process, especially for five small millets and the lack of 'modern' millet-based foods in the market.

The constraints pertaining to quality seed production in millets are given below:

- **Low productivity of millets:** Millets have lower productivity as compared to cereal crops like wheat, rice and maize, which is attributed to availability of limited cultivars, non-adoption of improved cultivars and their cultivation in marginal lands under rainfed conditions. Hence, the yield gap in millets is largely a reflection of farmers' cultivation technologies and there is lot of scope for improvement. The country's average yield gap for rabi sorghum, kharif sorghum, bajra, ragi and small millets over 2009-2014 were 58%, 151%, 62%, 183% and 156%, respectively.

- **Non- availability of resistant cultivars to pests and diseases:** Though millets have minimal pests and diseases, some pests and diseases often cause significant losses in sorghum (shoot fly, stem borer, grain mold), pearl millet (downy mildew and blast) and finger millet (blast). Moreover, there are no productive cultivars with highly significant resistance to these pests and diseases and management options are mostly limited to agronomic and chemical methods.
- The indenting from state government is almost nil, especially for small millets though some high yielding varieties are available. Hence, the farmers have to rely upon farmers' saved seeds
- Low SRR (Seed replacement rate) and VRR (variety replacement rate)
- Lower profitability and lack of commercialization leading to millets being less remunerative crops due to lower yields coupled with declining prices due to vulnerable quality to environmental factors (e.g., as in the case of Kharif Sorghum)
- **Inadequate support to R&D research efforts for improving the millets cultivation**: While aligning more resources for the improvement of fine cereals, millets were not given adequate importance in research and development on improved varieties, productivity, diversification of processing technologies and marketing
- Thelocation specific seed production techniques have not been worked out in especially in minor millets
- Lower or near absence of production support when compared to the support enjoyed by other crops, in terms of input supply and subsidy, and competition from other market friendly remunerative crops,
- **Availability of other fine cereals at incentivized prices:** Fine cereals such as Rice and Wheat have been made available at incentivized prices through PDS, MDM, WCD and other publicfunded feeding/nutritional programmes
- Lack of public procurement and marketing support
- Near lack of reach of improved methods of production and technologies like improved varieties to small millet farmers (except finger millet in certain pockets)
- Lack of MSP for Small Millets has slowed their area expansion and consequently the production and supply are hampered.
- **Changing consumer tastes and preferences:** Over the decades, consumer preferences have shifted to tastier and convenient foods either by demonstration effect of western culture or "indigenous misconception that millets are poor man's foods.

A total 673 varieties of millets have been released since 1969, out of which 194 varieties were released during 2014-22. ICAR-Indian Institute of Millets Research (IIMR), Hyderabad and AICRP Project on Millets have succeeded in development of more than 90 varieties for different agro-climatic regions so far. Recently, Hon'ble Prime Minister of India dedicated to the nation ICAR developed 3 bio-fortified varieties of millets (Finger millet - 2, Small millet -1) with high iron and zinc contents on the occasion of

75th Anniversary of UN FAO. A total of 13 bio-fortified varieties have been released till date, including 9 in pearl millet, 3 in finger millet and 1 in small millet. To promote millet production, a new Sub-Mission on Nutri-cereals (Millets) under National Food Security Mission Programme was implemented in the year 2018 to increase area, production and productivity of millets in 212 districts of 14 states. Consequently, the production of millets has increased from 13.7 million (2018–19) to 17.9 million tonnes (2020–21). The other important decisions taken were changing the name from millets to nutri-cereals through a Gazette Notification of GoI in April 2018, implementation of National Year of Millets 2018, launching of breeder seed production at 18 centers and creation of 25 seed hubs at ICAR-AICRP and KVK's. To create domestic and global demand and to provide nutritional food to people, UN has declared 2023 as International Year of Millets.

Future prospects:

1. **Area expansion in non-traditional areas:** The millets cultivation can be expanded to fallow and wastelands and the non-traditional areas, which are more sustainable without competing with the high remunerative crop, thus increasing the overall production.
2. **End-product specific cultivars:** Geometrical and nutritional evaluation of several cultivars available in all the major millet growing areas and mapping them to the suitable end-use is essential for better end-product quality and scaling up the value addition by the giant processors
3. **Seed hubs & breeder seed production:** There is a huge need for identifying various product-specific cultivars and establishing the seed hubs for breeding and producing such seeds so as to establish demand-driven production. The development of seed hubs that can deliver quality seed at high production levels is an important intervention
4. Promotion of seed indenting system of small millets by the public and private sector
5. Policy initiatives to enhance VRR and SRR in millet crops
6. Public private partnership for enhancing the production and distribution of quality seed of millet crops
7. FPOs/ Co-operative and Farmers participatory seed production for enhancing seed supply at the local level.
8. Effective implementation of seed village scheme of millet seed production and distribution.
9. Demand creation: Mainstreaming Millets in ICDS/MDM/PDS and to the food plate all to enhance household consumption for Nutrition security
10. International Centre: Upgradation of ICAR-IIMR as Global hub on R&D, Capacity building, Value Addition, Entrepreneurship Development & Incubation
11. Creation of Awareness: National and International Outreach Programs through Ministry of Tourism and Ministry of External Affairs

The global scenario of millets production has been almost stable from the perspective of sorghum, pearl millet and finger millet. In India, area under millets has been decreasing drastically over years, despite the high adaptation of these crops to difficult and niche areas, climate-friendly cultivation and nutritious produce. These crops are receiving the due importance in the country and across the world due to the efforts of Government of India and United Nations, thus necessitating expansion of area under their cultivation and enhancing productivity. The Union Budget 2023-24 has highlighted the importance of coarse grains or millets as means of sustainable cultivation that can raise the income of small farmers in arid regions besides providing food and nutritional security globally. The Union Budget 2023-24 highlighted that to make India a global hub for Shree Anna Research, the Indian Institute of Millet Research in Hyderabad will be made into a center of excellence for sharing best practices, research and technology at the international level.

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PRODUCTION AND POTENTIAL OF MILLETS UNDER NATURAL FARMING FOR SUSTAINABLE FOOD SECURITY

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Rising population at global level needs solving the problems related to food and health due imbalance use of fast foods of high calories. The problems of obesity, diabetes, cardiac arrests, porous bones, depressions etc. are so called general diseases of modern era. So many cereals are available which economically feasible and tasty but not healthy. At present people are very conscious with health. Millets are one of the best solutions to found highly nutritious and health benefits in pandemic era. Millets are a collective group of small seeded annual grasses and are believed to be among the earliest domesticated plants, which have long served as traditional staple crops for millions of farmers. Millets form a relatively inexpensive source of nutrition especially to the underprivileged population of the world. Over the years notwithstanding the wide range of benefits that millets provide, they have largely been missing from the staple crops due to inadequate knowledge of their benefits compounded by changing dietary habits. In the recent years, lot of efforts have been taken by various government, and non- government organizations to promote millets as an important dietary choice especially to ensure nutrition security for all. In this context, it is significant to note that the proposal of Government of India to United Nations for declaring 2023 as International Year of Millets was supported by 72 countries and United Nations' General Assembly (UNGA) declared 2023 as International Year of Millets on 5th March, 2021. Helping millets make a comeback is not just popularization of a neglected and underutilized crop but also an effort to achieve the sustainable development goals (SDGs) – mainly SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 12 (sustainable consumption and production), and SDG 13 (climate action). In the search for climate resilient solutions, millets could be a crucial link in sustaining the food supply chain especially for the less privileged nations.

Millets consumed by more than one third population of the world. Traditional consumers are used millets as a food in limited area in limited area where the cultivation and underutilized. The processing has a method for the formulation of fortified and value-added products. Different types of products are prepared viz ready to use, ready to cook, and ready to eat, these would help to increasing the consumption of millets for the non-millet consumers.

Nutritional importance of millets

There are many chronic illnesses and health problems in the world today. In 129 nations, 44% of the population suffers from very serious levels of undernutrition, adult overweight, and obesity, according to the 2016 World Nutrition Report [IFPRI. (2016)]. The majority of these disorders are caused by nutrient imbalances in the diet. United Nations Food and Agricultural

Organization estimates that 7.9% of the world's population, or 795 million people, were undernourished in 2015. Nonetheless, more than 1.9 billion adults under the age of 18 (or 39% of the world's population) were reported to be overweight, and another 13% to be obese [FAO, 2015 and WHO, 2015]. Obesity is also a major health concern in India with the prevalence rate of 11% in men and 15% in women. Millets secure sixth position in terms of world agricultural production of cereal grains and are still a staple food in many regions of world. These are rich source of many vital nutrients and hence, promise an additional advantage for combating nutrient deficiencies in the third world countries. Millets have comparable or better nutritional value than other major cereal grains. The millets' other advantages—gluten-free proteins, high levels of fibre, low glycemic index, and a wealth of bioactive compounds—made them an ideal health food (Kannan et al., 2013). Millets typically contain 56.88 to 72.97 g of carbohydrates per 100 g. Barnyard millet was found to contain the fewest carbohydrates [Saleh et al., 2013].

The protein level of all millets is comparable to one another, with an average protein content of 10 to 11%, with the exception of finger millet, which has been found to possess protein in the range of 4.76 to 11.70 g/100 g in various studies [Baebeau and Hilu 1993]. The essential amino acids methionine, valine, and lysine are among those present in finger millet protein, which includes 44.7% of all amino acids [Mbithi-Mwikya et al., 2000].

Millets have a far higher mineral content than common cereals like wheat (1.5%) and rice (0.6%), ranging from 1.7 to 4.3 g/100 g. In India, calcium and iron insufficiency are extremely common [Aggarwal et al., 2012], and osteoporosis affects a significant portion of the adult population. Finger millet has a calcium concentration that is around eight times higher than wheat's (348 mg/100 g), making it the best food for preventing osteoporosis. Both pearl millet and barnyard millet are excellent sources of iron, and pregnant women with anaemia can get all the iron they need by eating both grains. Barnyard millet has an iron concentration of 17.47 mg/100 g, which is only 10 mg below the daily need.

Amongst the millet, foxtail millet has the greatest concentration of zinc (4.1 mg/100 g), and it is a rich source of iron (2.7 mg/100 g) as well [Chandel et al 2014]. Certain nutrients, namely zinc and iron, are crucial for boosting immunity. In particular, millets are a good source of ribofavin, niacin, and folic acid as well as beta-carotene and B vitamins. Millets have thiamine and niacin levels that are similar to those of wheat and rice. Foxtail millet has the highest thiamine concentration of any millet, 0.60 mg/100 g.

The amount of riboflavin in millets is significantly higher than that in common cereals, with barnyard millet having the highest level at 4.20 mg/100 g, followed by foxtail millet at 1.65 mg/100 g and pearl millet at 1.48 mg/100 g. Nutritional deficits can be eliminated by including millets in the diet. The use of millet four as a vehicle for iron and zinc fortification in India has been advocated by Platel et al. (2013). Moreover, millets are free of gluten and may be anti-carcinogenic [Dykes et al., 2006].

Table 1: Nutritional content in 100 gram of dry grains

Millets	Protein (gram)	Carbo-hyderate (gram)	Fat (gram)	Minerals (gram)	Fiber (gram)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Energy (Kcal)	Thiamin (mg)	Niacin (mg)
Foxtail	12.3	60.2	4.3	4	6.7	31	290	2.8	351	0.59	3.2
Little	7.7	67	4.7	1.7	7.6	17	220	9.3	329	0.3	3.2
Kodo	8.3	65.9	1.4	2.6	5.2	35	188	1.7	353	0.15	2.0
Porso	12.5	70.4	1.1	1.9	5.2	8.0	206	2.9	354	0.41	4.5
Barnyard	6.2	65.5	4.8	3.7	13.6	22	280	18.6	300	0.33	4.2
Sorghum	10.4	70.7	3.1	1.2	2.0	25	222	5.4	329	0.38	4.3
Pearl	11.8	67	4.8	2.2	2.3	42	240	11	363	0.38	2.8
Finger	7.3	72	1.3	2.7	3.6	344	283	3.9	336	0.42	1.1
Peddy Rice	6.8	78.2	0.5	0.6	1.0	33	160	1.8	362	0.41	4.3
Wheat	11.8	71.2	1.5	1.5	2.0	30	306	3.5	348	0.41	5.1
Quinoa	14	64	6	-	7	36	457	4.6	368	0.36	-

Source: NIN, Hyderbad

Table 2: Health Benefits of Millets

Types of Millets	Health Benefits
Finger millet	Inhibit cataract eye lens, Lower plasma glucose level, Antimicrobial activity against Bacillus cereus and Aspergillus, flavus
Foxtail millet	Anti hyperglycemic activity
Proso millet	Improved HDL, Lower triglycerides, Prevent cardiovascular disease
Kodo millet	Inhibit glycation and cross linking of collagen leads to inhibition of aging
Pearl millets	Inhibiting the growth of the phytopathogenic fungi
Barnyard millets	Improved the levels of HDL
Little millet	Inhibitory effects on lipid peroxidation

Source:Verma *et al.*, (2012) : Fereidoon Shahidi *et al.*, (2013)

Millet under natural farming

For centuries, millet cultivation and organic farming were ubiquitous across India. Millet can be alternate option of major cereals crop due to its wider acceptability under the unusual situation in changing climatic scenario. They can easily thrive in extreme conditions like drought, and some wild varieties can even prevail in fooded areas and swampy grounds.They are climate-smart and can be grown in drought-hit, arid regions more successfully than any other crop. They also have an extremely low water footprint, with a crop of millets requiring around 80 percent less water than crops like rice, wheat, or sugarcane. Another, often overlooked, positive of cultivating millets is that they are excellent for soil preservation. Similarly, natural farming is a low-input, climate-resilient type of farming that encourages farmers to use low-cost locally-sourced inputs, eliminating the use of artificial fertilizers, and industrial pesticides. Natural

farming was first popularized by the Japanese scientist and philosopher, Masanobu Fukuoka, who practiced it on his family farm in the island of Shikoku (Fukuoka, 1985). Natural farming eliminates energy/ production costs, fertilizer and other input costs, improves underground water level without any contamination, helps in conserving moisture and prevent crop from effect of climate change. Above all, it reduces global warming by reducing the greenhouse gases emission and helps in sustainable food grain production to feed the increasing global population. It cannot be an exaggeration, if we say that cattle based natural farming has the answer for the problem of farmers suicides, mitigation of economic recession, empowerment of the farmers' and improvement of the rural economy. There are four integral part of the natural farming namely (1) beejamrutham, or microbial coating of seeds using cow dung and urine based formulations; (2) jeevamrutham, or the application of a bio inoculum made with cow dung, cow urine, jaggery, pulse flour, water and soil to multiply soil microbes; (3) mulching, or applying a layer of organic material to the soil surface in order to prevent water evaporation, and to contribute to soil humus formation; and (d) wapasa, or soil aeration through a favorable microclimate in the soil. For insect and pest management, natural farming encourages the use of various kashayams (decoctions) made with cow dung, cow urine, lilac and green chillies. The potential benefits of technique are; it creates conductive environment for biological processes in the soil, most of the freely available resources in nature are used in this technique, production is non toxic, without use of chemicals and fertilizers will reduce subsidy burden of these inputs and minimizes the risk of crop failure, etc. Under natural farming, millets can be raised successfully because millets are resilient and rain-fed crops that thrive in dry regions and grow well in conditions of low soil fertility and moisture where on farm available inputs can be successful utilize for higher production and productivity.

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SMALL MILLETS IN INDIA: PRESENT STATUS & CROP IMPROVEMENT EFFORTS

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The group of small millets in India include finger millet (*Eleusine coracana*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*), barnyard millet (*Echinochloa frumentacea*), proso millet (*Panicum miliaceum*) and browntop millet (*Urochloaramosa*). These are one of the oldest cultivated food grains known to humans, and have a unique place in Indian agriculture though they contribute less than 1% to the annual cereal grain production. Traditionally these crops have been the indispensable component of dry farming system. Often they are grown in areas where no other food crop is economical. These are drought tolerant, climate resilient and hardy crops, and quite adaptable to poor soil fertility and limited precipitation between 200 and 500 mm, and often grow under non-irrigated conditions in shallow soils. Because of their better adaptability (compared to fine cereals), they play a vital role in agriculture on marginal lands, especially in the semi-arid tropics and hilly terrains supporting millions of poor and food insecure people. Because of the nutritional superiority with respect to protein, fibre, calcium and mineral contents, these are now referred "Nutri-cereals".

Status of small millets in India

Small millets are regionally important crops. Finger millet is the most important crop grown in many states of India from sea level in coastal Andhra Pradesh to 8000 feet altitude in Himalayas. Karnataka is the major finger millet growing state accounting to 65% of area and production (2019-20) followed by Uttarakhand and Tamil Nadu. The other small millets (little, kodo, barnyard, foxtail, proso and browntop millet - arranged in the decreasing order of area under cultivation) are mostly concentrated in specific states/regions. For example little millet is mostly grown in Odisha, Madhya Pradesh and Chattisgarh, while kodo millet is mostly found in Madhya Pradesh, Chhattisgarh, Tamil Nadu and Gujarat. Barnyard and proso millets are grown largely in hills of Uttarakhand, North-Eastern region and plains of North Bihar. Foxtail millet is largely grown by Andhra Pradesh and Karnataka. Browntop millet is confined to a very limited area in Karnataka (Tumkur, Chitradurga, Chikkaballapura) and Andhra Pradesh (Ananthpur). The state-wise area, production and productivity of small millets are given in Table 1.

Decline of small millets in India

In spite of the nutritional superiority and capabilities of millet farming systems, the area under millet production has been drastically decreasing over the last six decades, especially since the Green Revolution. The area under small millets has declined considerably in all the states where they were predominantly grown in the past. The major reasons for losing the area under small millets cultivation being introduction of high yielding varieties of different crops; shift from millets to more profitable crops in *kharif* such as soybean, maize, cotton and sunflower in different states; changing food habits and consumer preferences due to rapid urbanization and

rising income levels; difficulty in processing of small millets; poor quality of the grains, lack of procurement and market support.

Table1. Area, production and yield of small millets in prominent states of India (2019-20)

State	Finger millet			Other small millets		
	Area ('000 ha)	Prodn. ('000 t)	Yield (kg/ha)	Area ('000 ha)	Prodn. ('000 t)	Yield (kg/ha)
Andhra Pradesh	33.6	44.3	1320	23.3	22.1	947
Arunachal Pradesh	-	-	-	26.8	27.5	1025
Chhattisgarh	4.5	1.2	267	63.1	18.3	290
Gujarat	11.6	10	862	8.2	13.6	1657
Jharkhand	14.6	12.8	875	-	-	-
Karnataka	673.7	1162.5	1726	52.4	38.1	727
Madhya Pradesh	-	-	-	79.8	73.9	926
Maharashtra	82.2	87.3	1061	76.4	30.9	405
Odisha	35.9	26.2	731	32.9	17	517
Rajasthan	-	-	-	10.1	5.2	518
Tamil Nadu	84.5	274.5	3246	17.9	26.3	1466
Uttarakhand	91.6	130	1419	50.3	68	1351
Others	10.8	13.2	1222	20.8	29.1	1399
All India	**1043**	**1762**	**1697**	**462**	**370**	**809**

(Source: Ministry of Agriculture, Govt. of India)

Share of small millets in the Gross Cropped Area has declined from 4.9% (finger millet – 1.6%, other small millets – 3.3%) during the period of 1956-61 to a level of 0.88% (finger millet – 0.56%, other small millets – 0.32%) during 2014-19. Share in the total food grains production has declined to a level of 0.71% (finger millet – 0.58%, other small millets – 0.13%) during the period of 2016-21 which was 5.2% (finger millet – 2.5%, other small millets – 2.7%) during 1956-61. The period between 1951 and 2021 saw a dramatic decline in cultivated area under small millets (52% for finger millet, 90% for other small millets) (Table 2). The total production of small millets has declined by nearly 44%, though not in the same rate as area. In case of finger millet, production has slightly risen by 12.5% from first five year plan to XII plan despite area reduction by more than half because of improvement in yield levels (from 649 kg/ha in 1950-51 to 1747 kg/ha in 2019-20) due to adoption of high yielding varieties and production practices by the farmers. In case of other small millets the production levels fell down by more than 80%, while productivity has risen marginally from 380 kg/ha (1950-51) to 800 kg/ha (2019-20) at all India level. Declining government support, and easy availability of rice and wheat to all sections

of the society especially through PDS have significantly contributed to this decline and fall of small millets in Indian agriculture.

Table 2. Quinquennial area, production and productivity of small millets in India

State	Finger millet			Small millets		
	Area ('000 ha)	Prodn. ('000 t)	Yield (kg/ha)	Area ('000 ha)	Prodn. ('000 t)	Yield (kg/ha)
1951-55	2274	1605	704	5290	2177	410
1956-60	2454	1873	764	5022	1955	389
1961-65	2555	1888	743	4677	1889	404
1966-70	2420	1887	779	4741	1784	376
1971-75	2442	2227	909	4489	1745	388
1976-80	2588	2650	1021	4326	1743	402
1981-85	2474	2612	1054	3459	1391	401
1986-90	2306	2510	1088	2754	1198	437
1991-95	1891	2511	1331	1950	851	439
1996-00	1718	2413	1402	1492	738	435
2001-05	1563	2088	1331	1173	510	435
2006-10	1350	1976	1471	970	467	480
2011-15	1179	1915	1625	683	412	606
2016-20	1033	1674	1612	523	386	739
2021-22*	1079	1700	1576	479	370	772

(Source: State of Indian Agriculture -different years, Agricultural Statistics at a Glance 2020, * As per 4th advance estimate 2021-22)

Crop Improvement efforts

As small millets are mostly confined to marginal lands, less attention was given to their improvement in spite of their nutritional superiority. In the initial years the crop improvement was confined to a fewer states such as Tamil Nadu, Andhra Pradesh, Karnataka and Uttar Pradesh. Finger millet work in Karnataka dates back to 1900, initiated at Bangalore; in Tamil Nadu during 1923 and in Uttar Pradesh at Kanpur and Gorakhpur in 1944. The emphasis was on varietal improvement through selection of better genotypes from local cultivars. The first finger millet variety released in India was H 22 as early as 1918 in Karnataka. During 1956, Project for Intensification of Regional Research on Cotton, Oilseeds and Millets (PIRRCOM) was launched and with this, several centres started working on millets. Crop improvement in millets in general started receiving attention with the launch of All India Coordinated Millets Improvement Project in 1969. However, except finger millet other small millets could not attract much attention from the researchers. During 1978-79 under International Development Research Centre (IDRC), Canada assistance five crop specific lead research centres were established for barnyard millet (Almora), proso millet (Dholi), kodo millet (Dindori), little millet (Semiliguda) and foxtail millet (Nandyal). This resulted in development of many new varieties and technologies. During VII

five year plan realizing the need for concerted efforts, ICAR launched a separate All India Coordinated Small Millets Improvement Project (AICRP-Small millets) in 1986 with its headquarters at GKVK, UAS, Bangalore. Following this, intensive efforts were made on improved cultivar development and crop management technologies. When the AICRP-Small millets were established the IDRC centres became part of it. The AICRP acts as the nodal agency to plan, coordinate and execute the research programmes to augment the production and productivity of seven small millets at all India level. The work is multi-disciplinary and applied in nature.

The crop improvement is aimed at developing high yielding varieties with resistance to blast disease, quality fodder, early and medium maturity in finger millet, resistance to head smut in kodo millet and resistance to shoot fly in both proso and little millets. Through the efforts of AICRP more than 230 high yielding varieties of six small millets were released in the last 35 years, which is nearly three times that of varieties developed (86) prior to launch of coordinated project. A number of improved varieties possessing higher yield, variable maturity, tolerance to various diseases and insect pests have been evolved and released for general cultivation across the country or for specific states. Significant genetic enhancement has been achieved in case of finger millet and satisfactory yield enhancement has been observed in kodo, foxtail and barnyard millets.

Future thrust areas

Though the goal of breeding small millets remains improvement of grain yield including maximization of biomass and the harvest index, cultivars need to be developed depending on the location specific requirements of soil, rainfall, temperature, humidity, day length and cropping patterns. Some of the future thrust areas for crop improvement include:

- Utilization of trait specific germplasm for crop improvement
- Standardization of crossing techniques to create large variability
- Resistance to biotic stresses (blast in finger millet, shootfly in little, proso and foxtail millets)
- Tolerance to abiotic stresses (drought, temperature, salinity)
- Improvement of nutritional quality, Biofortification and bioavailability
- Varieties suitable for specific end uses like popping and malting, etc.
- Dwarf varieties with uniform maturity for mechanization to reduce cost of cultivation
- Application of molecular tools, gene discovery and allele mining for water and nutrient use efficiency and nutritional quality
- Quality seed production of improved varieties and promoting varietal spread

INSECT PESTS OF MILLETS & THEIR MANAGEMENT

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Millets are collective group of small seeded annual grasses that are grown as grain crops, primarily on marginal land in dry areas of temperate ,sub tropical and tropical regions. These form the staple food of the poorest of the poor and a larger section of tribal and hill peoples. India produces >170 lakh ton (80% of Asia's & 20% of global production). Global average yield: 1229 kg/ha, India (1239 kg/ha). The evolution of new and high yielding small millet varieties may encourage the buildup of insects which were not predominant before. The major insect pest species that attack millets and their management practices are presented. A list of insect pests associated with millets is given in Table 1. The major pests are shootfly on different small millets, stem borers, earhead worms and aphids on finger millet and army worms, leaf rollers and leaf beetles on foxtail millet. Other potential and occasional pests which infest the millets in limited areas are gall midge in little and kodo millets, leaf miner in foxtail millet, termites in proso millet, stem borer in barnyard millet and leaf hoppers and root aphids in finger millet. Other minor pests though present in the field do not cause economic losses and are of secondary importance (*e.g.* white grubs, bugs, and grasshoppers).

Table 1: Insect pests on millets in India

Common name	Scientific name	Order	Family	Status
1. Kodo millet (*Paspalum scrobiculatum* L.)				
Gall midge	*Orseolia* sp.	Diptera	Cecidomyiidae	Moderate
Gundhi bug	*Leptocorisa acuta* (Thunberg)	Hemiptera	Alydidae	Minor
Jassid	*Hecalus* sp.	Hemiptera	Cicadellidae	Minor
Leaf roller	*Marasmia trapezolis* Wlk.	Lepidoptera	Crambidae	Minor
Shootfly	*Atherigona simplex* Thom.	Diptera	Muscidae	Major
Stem or Pink borer	*Sesamia inferens* Wlk.	Lepidoptera	Noctuidae	Moderate
Army worm	*Mythimna separata* Wlk.	Lepidoptera	Noctuidae	Minor
Grasshopper	*Acrida exaltata* Wlk.	Orthoptera	Caelifera	Minor
2. Foxtail millet - *Setaria italica* Beauv.				
Ant	*Sima sp.* nr *longiceps* Foral	Hymenoptera	Formicidae	Minor
Army worm	*Mythimna separata* Wlk.	Lepidoptera	Noctuidae	Mod-Major
Flea beetle	*Chaetocnema basalis* Baly. *Madurasia* sp	Coleoptera	Chrysomelidae	Mod-Major

Common name	Scientific name	Order	Family	Status
Leaf roller	*Marasmia trapezolis* Wlk	Lepidoptera	Crambidae	Mod-Major
Shootfly	*Atherigona atripalpis* M.	Diptera	Muscidae	Moderate
Stem borer	*Chilo partellus* Swim	Lepidoptera	Crambidae	Minor
Surface grasshopper	*Chrotogonus* sp.	Orthoptera	Pyrgomorphidae	Minor
3. Little millet - *Panicum miliare*. Lam.				
Black pentatomid	*Dolycoris indicus* Stal.	Hemiptera	Pentatomidae	Minor
Flea beetle	*Chaetocnema* sp.	Coleoptera	Chrysomelidae	Minor
Gall midge	*Orseolia* sp.	Diptera	Cecidomyiidae	Moderate
Grass hopper	*Acrida exalta* Wlk.	Orthoptera	Caelifera	Minor
Jassid	*Kolla mimica* Dist.	Hemiptera	Cicadellidae	Minor
Shootfly	*Atherigona miliaceae* M.	Diptera	Muscidae	High
Stink bug	*Nezara viridula* Linn.	Hemiptera	Pentatomidae	Minor
4. Proso millet - *Panicum miliaceum* L.				
Field cricket	*Brachytrupes* sp.	Orthoptera	Gryllidae	Minor
Shootfly	*Atherigona miliaceae* M.	Diptera	Muscidae	Major
Termites	*Odontotermes* sp. *Microtermes* sp.	Blattodea	Termitidae	Moderate
5. Barnyard millet - *Echinochloa frumentacea* (Roxb.) Link				
Aphid	*Hysteroneura setariae* (Thomas)	Hemiptera	Aphididae	Minor
Grass hopper	*Acrida exaltata* Wlk.	Orthoptera	Caelifera	Minor
Leaf caterpillar	*Euproctis* sp.	Lepidoptera	Erebidae	Minor
Pink stem borer	*Sesamia inferens* Wlk.	Lepidoptera	Noctuidae	Moderate
Shootfly	*Atherigona falcata* Thom.	Diptera	Muscidae	Major
White grub	*Anomala dimidiata* Burm. *Holotrichia seticollis* Mos.	Coleoptera	Scarabidae	Minor
6. Finger millet - *Eleusine coracana*, Gaertn.				
Pink stem borer	*Sesamia inferens* Wlk.	Lepidoptera	Noctuidae	Major
White stem borer	*Saluria inficita Wlk*	Lepidoptera	Pyralidae	Minor
Sorghum stem borer	*Chilo partellus* Swin	Lepidoptera	Crambidae	Moderate
Earhead caterpillar	*Cryptoblabes gnidiella*	Lepidoptera	Pyralidae	Major

Common name	Scientific name	Order	Family	Status
	M. *Heliothis armigera* Hb. *Eublemma silicula* Swin *Cacoecia epicyrta* Meyr.		Noctuidae Noctuidae Tortricidae	
Red hairy caterpillar	*Amsacta albistriga* Wlk	Lepidoptera	Erebidae	Minor
Aphid	*Hysteroneura setariae* Them.	Hemiptera	Aphididae	Major
Root aphid	*Tetraneura nigriabdominalis* Sasaki	Hemiptera	Aphididae	Moderate
Leaf hopper	*Cicadulina bipunctella bipunctella* Matsumra	Hemiptera	Cicadellidae	Mod-Major
Leaf hopper	*Cicadulina chinai* Ghauri	Hemiptera	Cicadellidae	
Surface grasshopper	*Chrotogonus* sp.	Orthoptera	Pyrgomorphidae	Minor
7. Pearl millet -*Pennisetum glaucum*				
Pink stem borer	*Sesamia inferens* Wlk.	Lepidoptera	Noctuidae	Major
White stem borer	*Saluria inficita Wlk*	Lepidoptera	Pyralidae	Major
Shootfly	*Atherigona approximata*	Diptera	Muscidae	Major
Grain midge	*Geromyia penniseti*	Diptera	Cecidomyiidae	Major
Stink bug	*Nezara viridula*	Hemiptera	Pentatomidae	Major
Leaf beetle	*Lema downsei*	Coleoptera	Galerucidae	Minor
Black hairy caterpillar	*Estigmene lactinea*	Lepidoptera	Arctiidae	Minor
Semilooper	*Antoba* (Eublemma) s*ilicula*	Lepidoptera	Noctuidae	Minor
Wingless grasshopper	*Neorthacris simulans*	Orthoptera	Acrididae	Minor
8. Sorghum millet - *Sorghum bicolor*				
Sorghum Shootfly	*Atherigona soccata*	Diptera	Muscidae	Major
Stem borer	*Chilo partellus*	Lepidoptera	Crambidae	Major
Pink stem borer	*Sesamia inferens*	Lepidoptera	Noctuidae	Major
Shoot bug	*Peregrinus maidis*	Hemiptera	Delphacidae	Major
Earhead bug	*Calocoris angustatus*	Hemiptera	Miridae	Major
Sorghum midge	*Contarinia sorghicola*	Diptera	Cecidomyiidae	Major
Aphids	*Rhopalosiphum maidis, Melanaphis sacchari*	Hemiptera	Aphididae	Major
Fall Army worm	*Spodoptera frugiperda*	Lepidoptera	Noctuidae	Major

Common name	Scientific name	Order	Family	Status
	JE Smith			
Earhead web worm	*Cryptoblabes gnidiella*	Lepidoptera	Pyraustidae	Minor
Gram caterpillar	*Helicoverpa armigera*	Lepidoptera	Noctuidae	Minor
Plant bug	*Dolycoris indicus*	Hemiptera	Pentatomidae	Minor
Stink bug	*Nezara viridula*	Hemiptera	Pentatomidae	Minor
Mirid bug	*Creontiades pallidifer*	Hemiptera	Miridae	Minor
Green slug caterpillar	*Thosea aperiens* Wlk	Lepidoptera	Cochlididae	Minor
Leaf roller	*Marasmia trapezalis*	Lepidoptera	Pyralidae	Minor
Flea beetle	*Cryptocephalus schestedii, Monolepta signata*	Coleoptera	Chrysomelidae	Minor
Redhairy caterpillar	*Amsacta albistriga, A. moorei*	Lepidoptera	Arctiidae	Minor
Semilooper	*Eublemma silicula*	Lepidoptera	Noctuidae	Minor
Weevils	*Myllocerus maculosus M. discolor,M. subfaciatus*	Coleoptera	Curculionidae	Minor
Wingless grasshopper	*Colemania sphenaroides*	Orthoptera	Acrididae	Minor
9. Brown top millet - *Brachiaria ramosa* (L.) Stapf				
Shoot flies	*Atherigona oryzae A.pulla , A. punctata*	Diptera	Muscidae	Minor
Caseworm	*Parapoynx stagnalis* Zeller	Lepidoptera	Crambidae	Minor
Red hairy caterpillars	*Amsacta albistriga , A.moorei*	Lepidoptera	Erebidae	Minor

1. Shootfly (*Atherigona* spp.)

Sorghum shoot fly populations are generally abundant during the rainy season under moderate temperatures and high humidity. An increase in shoot fly populations is generally recorded 20 to 30 days after the onset of monsoon rains.

Hosts: Sorghum, pearl millet, wheat, maize, lemongrass, finger millet, goose grass etc.

Wild hosts: Sprawling panicum, bahama grass, bamboo grass, crab grass, barngrass, barnyard grass, tropical cupgrass, delicate lovegrass, buffalo grassmillet), creeping panic, kodo millet, feather grass, corn grass, cat's tail grass , bristly foxtail, aleppo grassm etc.

Nature of Damage

Damage by the sorghum shoot fly at the seedling stage (5 to 30 days after seedling emergence) leads to typical dead heart symptoms. The maggot cuts the growing point, and as a result the central leaf dries up forming a dead heart, which can be pulled out easily and produces

a typical offensive smell. Normally the damage occurs 1 to 4 weeks after seedling emergence. Plants of 5 to 30 days old are generally susceptible to shoot fly damage. Older plants (>30 days after seedling emergence) are not damaged by the sorghum shoot fly. However, under conditions of high humidity during the rainy season, shoot fly infestation may occur, but the infested plants do not produce the typical dead heart symptoms. The damaged leaf becomes thin and papery, and wraps around the other leaves. As a result, the plants may fail to grow normally. Late infestations may also damage the panicle in the formative stage, resulting in rotting or drying up of a portion of the panicle affected by shoot fly damage. Shoot fly-damaged plants also produce axillary tillers, which often serves as a means of recovery for the plant unless the tillers are not exposed to another spell of shoot fly-infestation in the susceptible stage (<20 days after initiation of tiller production).

The larva migrates to the upper side of the leaf, and moves along the leaf whorl till it reaches the growing point. It first makes an incision at the growing point, and as a result, the central leaf begins to dry up. The larvae feed on the decaying tissue of the central leaf inside the shoot causing the production of dead heart; such symptoms are evident 2 to 3 days after infestation. As a result of damage to the growing point, the damaged plant produces side tillers, which at times serve as a mechanism of recovery resistance. Some seedlings may not have typical dead heart symptoms, but still produce side tillers in response to temperature or moisture stress. Some genotypes have an inherent capacity to produce more tillers. Plants of >35 to 45 cm in height do not produce dead heart symptoms, and such plants have damaged leaf margins or partially damaged panicles.

Biology

Shoot fly females are attracted to the host plant for oviposition by the odours emanating from the host plant. Females of *A. soccata* lay cigar-shaped eggs singly on the lower surface of the leaves, at the 1- to 7-leaf stage. Eggs are laid generally singly parallel to the midrib on the under surface of the 3rd to 5th leaf. Under high shoot-fly pressure, there may be several eggs on the same leaf. Eggs hatch in 1 to 2 days. Where more than one egg is present, these are laid by different females, and normally only one maggot per plant is observed. There are three distinct peaks (6 to 7, 13 to 14, and 18 to19 days of age) in egg-laying activity. Most eggs (60%) are laid between 08.00 and 12.00 h. Egg-laying by *A. soccata* females is prolonged, when provided with the susceptible host, which may partly account for the marked increase in shoot fly damage as the crop season advances, because there is a considerable increase in active females in the presence of the preferred host plant.

After eclosion, the larva moves to the leaf whorl, and reaches the growing point through the leaf sheath. It cuts the growing point, resulting in wilting and drying of the central leaf, known as dead heart. The larva feeds on the decaying plant tissue. The dead heart can be pulled out easily, and it produces an offensive smell. Larval development is completed in 8-10 days, and pupation takes place mostly at the base of the stem, and sometimes in the soil. The entire life cycle is completed in 17 to 21 days. The adults are active throughout the day. Each female lays about 40 eggs.

The shoot-fly population begins to increase in July, peaks in August-September, and declines thereafter. Infestations are high when sorghum plantings are staggered due to erratic

rainfall. Shoot-fly infestations are normally high in the post-rainy season crop planted in September-October. Temperatures above 35°C and below 18°C , and continuous rainfall reduce shoot fly abundance. During the off-season, the insect survives on alternative hosts (*Sorghum* spp., *Echinochloa colonum*, *E. procera*, *Cymbopogon* sp., *Paspalum scrobiculatum* and *Pennisetum glaucum*), tillers of ratooned crop and volunteer /fodder sorghum.

Management

Cultural Practices

Date of sowing: Early plantings with the onset of monsoon results in low infestation of shootfly in kodo, little and proso millets with concomitant increase in yield than late planting.

Spacing: Closer spacing may either favour some pest species or may increase the effectiveness of the natural enemies in reducing the pest populations. Low plant densities contribute to decrease in the incidence of shootfly in kodo and little millets. Whereas, higher plant density increases number of shootfly, eggs laid and plants attacked in sorghum. .

Nutrients: The use of fertilizers to enhance plant nutrition often influenced the longevity and fecundity of insects and mites and the also the damage they cause. Sowing with no nitrogen recorded low incidence of shootfly in kodo and little millets.

Intercropping: Modification of the micro-environment in intercropping and differences in nutrient uptake by the intercrops may influence plant infestation and the development and movement of insect pests. Intercropping of soybean and radish in little millet substantially reduce the shootfly occurrence as compared to sole millet or millet mixed with French bean, ladies finger or pigeonpea. Intercropping of mung bean (*Vigna radiata*) or urd bean (*Vigna mungo*) and pigeonpea reduced the succession and build up of insect pests in sorghum and pearl millet.

Weeding: Elimination of weeds reduce shootfly infestation in kodo millet.

Crop rotations and cropping systems: Crop rotations can be employed to minimize pest damage by confusing the insects with the chemical cues emanating from non host plants, and using crop combinations that encourage the activity and abundance of natural enemies. Sorghum is generally rotated and /or intercropped with cotton, groundnut, sunflower or sugarcane. This may reduce the damage caused by *A. soccata*. A. soccata damage is also reduced when sorghum is intercropped with leguminous crops. **Field sanitation and tillage:** Shoot fly infested seedlings/tillers should be removed from the field and destroyed. Collecting and burning of sorghum stubbles with tillers and alternative hosts of sorghum shoot fly, which act as an important source of carryover of shoot fly populations during the off-season, can help to reduce build up of shoot fly populations.

Fallowing and closed season: Keeping the lands fallow reduces the carryover and build-up of pest populations from one season to the next. Observing a closed season during summer for 2 months reduces the carryover and population build up of *A. soccata*.

Chemical Control: Methyl demeton and quinalphos effectively reduce shootfly infestation in little millet, barnyard millet and proso millet. Fishmeal + propoxur bait, foliar spray of Benfuracarb and imidacloprid or seed treatment with imidacloprid 75 WS are also effective for shoot fly control.

Biological Control

Farming systems, crop combinations and crop cultivars that encourage the activity of natural enemies can play an important role in integrated pest management. *Abrolophus* sp., *Tetrastichus nyemitawus* and *Trichogramma* spp., are important natural enemies of sorghum shoot fly.

However, a harmonious combination of early sowing, judicious use of available chemicals combined with resistant varieties and effective parasites would be the appropriate solution in shootfly management.

2. Pink stem borer (*Sesamia inferens* (Walker)

Hosts: *S. inferens* is highly polyphagous preferring Gramineae to Cyperaceae . It attacks rice, sugarcane, maize, common sorghum, wheat, millet, oats, Job's-tears, lemongrass, coco grass, Japanese millet, barngrass, barnyard grass, tropical cupgrass, finger millet, goose grass, barley, wrinkled duck-beak, Chinese fairygrass, buffalo grass, creeping panic, kodo millet, pearl millet, common reed, wild sugarcane, saltmarsh bulrush, foxtail millet, cat's tail grass , aleppo grass, Sudan grass, wheat etc.

Nature of Damage

Feeding occurs within the stem or base of the panicle of the host plant. When a stem is severed it wilts causing a dead heart. Feeding at the base of the panicles often causes the panicle to be cut leading to a wilted panicle called a whitehead. Exit holes along the tillers may be visible at close inspection. These symptoms are common for most stem borers and not unique to *S. inferens*.

Biology

There are three generations in temperate regions and six in the tropics. Eggs are laid openly behind leaf sheaths in rows (usually 3-8) resembling beaded strings. A single egg batch has 75-100 eggs. Fecundity averages 250 eggs with a high of 300-400 eggs per female. The female deposits several batches of eggs over a period of weeks. The second batch usually has the most eggs. The female mates usually only once. Incubation takes 6-10 days with an average of 7-8 days in the tropics.

Newly hatched larvae can bore into the stem without coming to the surface of the plant. Others disperse to neighboring plants which is why most infested tillers have only one larva but at times can have over ten. During their development, larvae may tunnel in several tillers. They disperse early and do not feed in groups. There are normally six or seven instars, but occasionally there can be eight. The total larval period may range from 28-56 days with an average in the tropics of 5 weeks. The first instar has a long developmental period of 8 days and the second to fifth instars average 3-5 days each, while the sixth averages 7 days and the seventh 13 days. The process to change into a pre-pupa takes about 5 hours. Pupation takes place in the larval tunnel but can occur between the leaf sheath and stem. Before pupating the larvae cut an exit hole in the stem for the adults to emerge. The larvae leave only a thin epidermis over the hole. The pupal stage lasts 8-11 days. The emergence of the adult takes about 25 minutes. The wings remain folded for 10 minutes initially then spread out fully. They are held vertically for 15

minutes before being lowered to their normal horizontal position. Normal flights take place within 4 days after emergence. There is no conspicuous pre-reproductive period and calling and mating occur within 24 hours after emergence. Adult females within 1 day after emergence were in the second phase of ovarian development and exhibited strong flight capability. *S. inferens* adults have strong flight capability with projected flight distances of females and males as more than 32 and 50 km, respectively.

Management

Cultural Practices

Cultural practices have a profound effect on *S. inferens*. Some methods are only effective if carried out through community-wide co-operation, others are effective on a single field. The community-wide practices act to prevent colonization and build-up, and have the greatest potential to minimize infestation. These include-

Date of sowing: Early planting will usually cause the crop to escape the period of peak population build-up.

Spacing: Increasing plant density ensures ample tiller densities to allow maximum compensation from damage

Nutrients: Using well timed and optimal levels of nitrogen and balanced fertilizer also aides a crop to compensate from damage even though it may increase the overall stem borer density.

Field sanitation and tillage: Good crop husbandry such as thorough land preparation, prompt weeding, and vigilant water management ensure vigorous crop growth and ability to tolerate stem borer damage.

Maturity: Early maturity is a mechanism to escape population build-up. Planting cultivars each season with the same maturity class and planting synchronously between fields . Photoperiod sensitive cultivars often suffer heavy infestations from stem borers as they allow more generations to build up on the crop.

Harvesting: Harvesting has a devastating effect on stem borers particularly if the straw is destroyed and the remaining stubble ploughed under.

Biological Control

Every life stage of *S. inferens* is vulnerable to attack by natural enemies. Once the eggs have been laid behind the leaf sheaths, the factors that will most reduce the stem borer population are natural enemies. A few parasites like *Apanteles flavipes*, *Bracon chinensis* and *Stenobracon* sp. have been reported

Chemical Control:

Stem borers are difficult to control with insecticides. After hatching, the larvae are only exposed for a few hours before penetrating a tiller. Successful control involves repeated foliar applications Foliar sprays act on the larvae, eggs and adults, but sprays also come into greater contact with natural enemies. Cases of stem-borer resurgence are not evident, although secondary pest outbreaks have been reported in areas where heavy insecticide usage is directed

against stem borers. Granular formulations give higher control than foliar sprays or dusts, particularly in high rainfall environments.

3. Fall army worm:

Fall army worm (FAW) is a polyphagous pest feeding on over 100 recorded plant species belonging to 27 families. However, it prefers plants from Gramineae family including many economically important plants such as maize, sorghum, millets, sugarcane, paddy, wheatetc. The young larvae (I^{st} to II^{nd} instar) scrape both of the leaves skeletonizing the upper epidermis leaving silvery transparent membrane. The III^{rd} instar larvae, the larvae enter the whorland inflict ragged edged oblong holes on leaf lamina presenting ragged edged holes. Once the larvae reaches fifth instar it feeds voraciously causing extensive defoliation of the whorl. On an average 1-2 larvae were found in each whorl.

Management

Following are the management options suggested to manage the pest.

General management measures

i. DeeploughingofthefieldexposestheFAWlarvaeandpupaetosunlightandnaturalenemies
ii. For synchronous planting sow the crop within the sowing window so that single stage ofcrop is available.
iii. Install pheromone traps @ 12 traps / ha for monitoring theFAW.
iv. Collection and destruction of egg masses/ larvae
v. Instalbirdperches@25/hasoonaftersowingasitfacilitatesmovementofinsectivorousbirds*viz.,* black drongo and blue jay which predate on larvae.

Early instar (I – II)

i. Treatthemilletseedwithmixtureof Cyantraniliprole19.8%+Thiamethoxam19.8%@4ml/ kg of seed as it protects the crop up to three weeks which in turn helps the crop to establish with good initial plant vigour.
ii. Whenincidenceisloworatearlyinstarstage(7-30dayoldcrop),sprayAzadirachtin1500ppm @ 5ml/liter or 5% Neem seed Kernel extract (NSKE).
iii. Spray fungal pathogen, *Nomuraea rileyi* (1 x 10^8 cfu@ 3 grams per liter of water in case of severe infestation(>10%damage)asalastresortspraycropwithSpinetoram11.7%
iv. SC @ 0.5 ml/l water or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water or Thiamethoxam12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water.
v. Alternate the chemical insubsequent sprays to avoid build-up of resistance in pest against insecticide.

Mid instar (III – IV)

i. Collection and destruction of larvae

ii. In case of severe infestation (10–20%damagedplants)spray Spinetoram 11.7 % SC @ 0.5 ml/l water or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water.

iii. Alternate the chemical in subsequent sprays. S

iv. Spray using high volume sprayer (Knapsack) preferably in the morning or evening with nozzle directed towards the whorls is advised.

Late instar (V- VI)

i. The late instar larvae are very difficult to manage using chemicals. In case of presence of late instar larvae poison baiting is suggested with fermented mixture of rice bran. Keep the mixture of 10 Kg rice bran + 2 Kg jaggery with 2-3 litres of water for 24 hours to ferment. Add 100 g Thiodicarb just half an hour before application in the field. The bait should be applied into the whorl of theplants.

ii. In case of severe infestation(>20%damagedplants)spraySpinetoram 11.7 % SC @ 0.5 ml/l or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water or or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/l of water.

iii. Sprayusinghighvolumesprayer,thenozzledirectedtowardsthewhorlsforbettercontrol.

iv. The subsequent spray may be taken up after 10 -15 days depending on the intensity of infestation avoiding the previously sprayedchemical.

Future research on -

Shootfly and Fall army worm on millets

Stem borers and earhead worms on finger millet

Aphids on finger millet and gall midges and borers on small millets

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SALVAGING MILLETS PRODUCTIVITY THROUGH DISEASE MANAGEMENT OPTIONS

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Millets are one of the oldest food grain crops and are generally grown in traditional agricultural systems with low inputs by resource poor farmers. These crops are known for their hardiness, nutritional qualities and medicinal benefits and have the capacity to give an assured harvest in both low as well as excessive rainfall conditions. Like other crops, these are also prone for attack by various pathogens like fungi, bacteria, viruses, nematodes and phanerogamic plant parasites, causing different diseases. These diseases occur during all the growth stages on different plant parts and reduce the grain yield as well as grain quality. Losses due to fungal diseases are more as compared to diseases caused by other pathogens. Some diseases were minor, now becoming major. Blast, downy mildew, ergot, smuts and rust are economically important diseases of most of the millets resulting enormous loss under favourable conditions. Anthracnose, charcoal rot and grain mold are important diseases of sorghum. Foot rot and narrow leaf spot of finger millet, leaf blight of little millet and browntop millet, sheath rot of kodo millet and banded leaf and sheath blight of all the small millets are emerging fungal diseases. Few diseases like udbatta of kodo millet, little millet, foxtail millet, leaf blight of kodo millet and grain smut of foxtail millet were reported earlier in sporadic form, but at times are reappearing in moderate to severe forms in different parts of the country. Looking to the status of farmers and growing patters of millets, use of resistant cultivars is the most economical, feasible and effective option for the management of diseases. Cultural practices and biocontrol agents are also effective to reduce the disease incidence. Cost effective chemicals may be used to control the diseases.

Introduction

Millets are a group of high valued coarse cereal crops cultivated by farmers in extreme climatic conditions. India is the largest producer of millets in the world with a share of about 41% (2020). In different parts of India, multiple varieties of millets i.e. pearl millet, sorghum, finger millet, kodo millet, little millet, barnyard millet, foxtail millet, proso millet and browntop millet are grown for grain and fodder. Among them, pearl millet contributes the largest share (60%) of the total millet production followed by sorghum (27%), finger millet (11%) and other small millets (2%). One of the major constraints to millet production is the biotic stresses particularly diseases, which are being caused by various fungi, bacteria, viruses, nematodes and phanerogamic plant parasites at global level. These pathogens infect different plant parts viz. roots, leaves, panicles. Grains at different stages of crop growth and adversely affect yield and quality of the produce.

Major diseases

Blast: Blast caused by *Pyricularia grisea* (finger millet, pearl millet, little millet, barnyard millet, browntop millet) and *P. setariae* (foxtail millet) is a potentially serious disease of millets occurs at all stages of plant growth. Blast of finger millet is economically the most

important disease followed by foxtail millet and pearl millet. The pathogen infects and develops elliptical, diamond or spindle shaped lesions on the leaf, neck (peduncle) and finger depending on the stages of crop. In finger millet, the most damaging stage is neck blast followed by finger blast. Yield loss varies depending on the onset of the disease, severity, crop variety and prevailing weather conditions. Average loss due to blast is reported 28-36% in finger millet and 30 to 40 % in foxtail millet. Moderate temperature, high humidity, cloudy days with intermittent rains is favourable for the spread of the disease.

Use of resistant cultivars has been the best and economical method for management of the disease. Seed treatment with tricyclazole @ 8 g/kg seed followed by one foliar spray of *Prosophis juliflora* (10% conc.) plant extract is effective. Two sprays of carbendazim (0.05%) or first spray of Chlorothalonil (0.2%) and second spray of mancozeb (0.2%) were found effective and economical. Seed treatment with *Trichoderma harzianum* and one spray of Pseudomonas fluorescens @ 0.3% at the time of flowering followed by second spray of P. fluorescens 10 days later can control all the blast infections.

Downy mildew: Downy mildew is important in pearl millet and foxtail millet caused by *Sclerospora graminicola*, sorghum caused by *Peronosclerospora sorghi* and finger millet caused by *Scleropthora macrospora*. The infection starts at seedling stage and continue till maturity of the plant. On sorghum and pearl millet, symptoms are visible on the lower surface of the leaf blade as white downy growth consisting of conidia and conidiophores of the pathogen, which later progresses upward. Barren inflorescence develops in pearl millet due to systemic infection. In finger millet, affected plants are generally stunted with shortened internodes, profuse tillering and plant assumes a bushy appearance known as crazy top or green ear symptoms. These green year symptoms are also common on pearl millet. A cool environment and high humidity favour the production of spore and the infection.

Crop rotation with other crops viz., pulses and oilseeds can minimize the primary inoculum of the pathogen. Use of resistant cultivars is the best option. Avoid the secondary spread of the disease by rouging out the infected plants. Seed treatment with Metalaxyl @ 2 g a.i.kg-1 seed controls the disease for about a month after sowing. However, seed treatment coupled with a single foliar spray with Metalaxyl or Mancozeb (0.2%) was found superior. A new formulation of metalaxyl Apron Star 42 WS for seed dressing is cost effective. Seed priming with chitosan gave systemic protection against downy mildew of pearl millet.

Ergot: Ergot or sugary disease is common on pearl millet (*Claviceps fusiformis*) as well as on sorghum (*Claviceps sorghi* and *C. africana*) and is a limiting factor for hybrid seed production. The disease has also quarantine implications. The disease is also reported in kodo millet at various part of India in sporadic form. First visible symptom of ergot infection appears as exudates of viscous pinkish to brownish in colour sweet liquid known as honey dew from the florets. The symptoms can be seen on a single, few or all florets of a panicle depending on severity of infection. Infected florets do not produce grain and adjoining grains from infected panicles show reduced germination. Ergot infection causes loss in seed yield as well as seed quality parameters. About 58 to 70% loss in grain yield of pearl millet and 10 to 80% in sorghum was reported due to ergot. But no authentic report on losses in kodo millet is available. The pathogen survives in the infected panicles left in the field and sclerotia that are mixed with the

seed during threshing and processing. Sclerotia contain alkaloids that affect the health of human beings and animals.

Use of resistant varieties, crop rotation with leguminous crops, Intercropping with pulses (Red gram) and removal of weeds from field are the eco-friendly management options, Early sown crops escapes as compared to late sown crops. To separate sclerotia use of 10% brine solution is recommended. Foliar spray with Ziram or a mixture of Copper oxychloride + Zineb (1:2), applied 2-3 times at 5-7 days interval started prior to earhead emergence is effective. Foliar spray of Captan @ 0.2% is also effective. Soil application of **T. viride** @ 500g/acre is also recommended. In pearl millet, the disease can be managed by pollen management that includes continuous supply of pollen by maintaining heterogenous plant populations of open pollinated varieties.

Smut: Smut is a fungal disease that converts the entire or part of an earhead into smut sorus. Four types of smuts namely head smut (sorghum, kodo millet, barnyard millet), grain smut (sorghum, little millet, barnyard millet, finger millet, proso millet), loose smut (sorghum) and long smut (pearl millet) are observed in millets. Sorghum is infected by all the four types of smuts. Head smut is soil borne, while grain smut and loose smut are primarily carried on the seed surface. Spores get adhered to the seed and germinates in the soil along with the seed. In long smut, the fungus survives as teliospores in infected seed as well as in soil. Teliospore germinates in optimum moisture and temperature and produce sporidia. Sporidium becomes air borne, falls on stigma and cause infection. In grain smut few to most of the grains of an infected earhead are transformed into smut sori covered with a membrane. The loose smut infected plants flower earlier than the healthy plants. All the spikelets of an infected earhead get malformed and hypertrophied. In case of head smut, a smut sorus entirely covered with a grayish white membrane emerged from the boot leaf in place of normal inflorescence. At maturity, fungal membrane ruptures releasing spore masses in the air leaving filamentous vascular tissues of the host. In case of long smut, the sorus is covered by a whitish to dull yellow thick membrane. The sorus is larger than grain and appears as enlarged body in place of grain. Grain losses up to 30% have been reported due to long smut in pearl millet. In India, generally smuts are observed sporidically on millets and are of minor importance.

Use of resistant cultivars, removal of infected heads, shallow sowing and application of nitrogenous and phosphatic fertilizer minimize the incidence of smut in millets. Seed treatment with *Trichoderma viride*, *T. harzianum* @ 4-6 g kg-1 seed or Seed treatment with Carboxin, Carbendazim, mixture of Carboxin + Thirum, Carbendazim + Mancozeb @ 2 g kg-1 seed is economical. Seed treatment & foliar spray of Triozol (Triadiminol) @ 0.2% at 5-7 days interval is effective. For grain smut of barnyard millet, seed treatment and foliar spray of Carbendazim or Tebuconazol @ (1%) is recommended. Seed treatment with *T. viridae* + 1 foliar spray of Carbendazim is very effective against grain smut of barnyard millet. Seed treatment with Carbendazim, Carboxin, Raxil , Chlorothalonil @ 2 g per kg seed is effective for the control of kodo millet head smut.

Rust: Almost all the millets are infected by rust causing pathogens namely *Puccinia purpurea* (sorghum), *P. subtriata* var. indica (pearl millet), *P. substriata* (kodo millet), *Uromycrs linearis* (little millet), *U. setariae italicae*(foxtail millet) and *U. eragrastidis*). In most of the cases, incidence occurs sporadically towards the end of the season and cause little damage to the

crop. If rust appears before the ear formation, the disease become serious and destroyed the crop. The rust symptoms appear as minute reddish to dark brown broken postules on both the surfaces of lower leaves. The rust is more severe in upper half of leaves as compared to the lower half. As the disease advances the infection spreads to the younger leaves. The disease may become severe under cool humid weather. Tan type varieties of sorghum and hybrids exhibits good amount of resistance to rust.

Use of resistant varieties, removal of alternate and collateral hosts reduces the rust incidence. Early sown crop escapes from rust incidence. Foliar sprays of Chlorothalonil (0.1%) or Mancozeb (0.2%) or Hexaconazol (0.1%) or Difenconazol (0.1%) or Propiconazol (0.1%) just after initiation of symptoms can control rust incidence effectively. Two sprays at 15 days interval immediately after appearance of symptoms is recommended for better management of the disease.

Anthracnose: Anthracnose caused by *Colletotrichum graminicola* is an important disease of grain forage and sweet sorghum but not observed on any other millets. The symptoms can appear as seedling blight, leaf blight, stalk rot and head blight. The disease has adverse effect on grain and stover yield, stover quality of forage sorghum and sugar accumulation in sweet sorghum. Grain yield losses may be up to 20 to 50% under severe conditions. Symptoms first appear on the leaf as minute elliptical to circular spots with straw colour centre and wide margin. Several spots may coalesce to give a blighted appearance on the leaf. Formation of a black dot like acervulus at the centre of necrotic spot is the characteristic symptom of the leaf anthracnose. The disease is more severe during extended periods of cloudy, warm, humid and wet weather.

Deep summer ploughing, clean cultivation and use of resistant cultivars reduces the disease incidence. Seed treatment with Carbendazim, Benlate, mixture of Carbendazim + Mancozeb @ 2 g kg-1 seed is effective. Foliar spray with Carbendazim (0.1%), Captafol, Chlorothalonil, Mancozeb, Zineb (0.2%) is also recommended. Seed treatment with Apron-plus (metalaxyl+carboxin+furathicarp) @ 1 g per kg seed along with foliar spray of Carbendazim+Maneb @ 0.2% or Mancozeb (0.2%) is effective.

Charcoal rot: Charcoal rot caused by *Macrophomina phasiolina* is an important soil borne disease of rabi sorghum in Maharashtra and Karnataka. The premature lodging of plant is the most apparent symptom of the disease. The pathogen infects root, destroying cortical tissues and may block water movement through vascular bundles. Rotting and breaking of the basal internodes cause lodging of the crop. Extensive lodging can cause 23 to 64% loss in grain yield depending on weather conditions and growth stage of cultivar at the time of infection.

Seed treatment with Trichoderma @ 4 g per kg seed or talk formulation of Pseudomonas chlororaphis SRB127 reduces the charcoal rot incidence and increases seed weight.

Grain mold: Grain mold of sorghum is an important grain disease of sorghum resulted 30 to 100% production losses depending on cultivars and prevailing weather conditions. Pearl millet, kodo millet, finger millet and barnyard millet are also infected with mold fungi occasionally. The disease reduces seed value, nutritive value of food as well as feed and cooking quality of the grain. Mold infection becomes visible in pink, orange gray, white or black colour fungal bloom on the grain surface. The severely infected grain becomes soft and disintegrates under slight pressure. The most common species causing mold are *Fusarium moniliforme*,

Curvularia lunata, Alternaria alternata and *Phoma sorghina*. Besides, many saprophytic fungi may also colonize mature grains. Moderate temperature (25-350C) and >90% relative humidity favours infection and subsequent disease development. In Kodo millet, a number of species i.e. *Phomopsis paspali*, *Fusarium gramearum*, *Aspergillus flavus* and A. tamari were found associated with kodo millet grains. Consumption of infected grains cause giddiness, vomiting, unconsciousness, difficulty in swallowing in humans and cattles, popularly known as kodo poisoning. Mycotoxins namely Paspalin P-I and P-II, Afla-toxin B 1 and Cyclopiazonic acid were isolated from kodo millet seeds.

Avoid harvesting & threshing of unripe or pre-mature grains. Protect the harvest with rains/moisture, because it makes the grains moldy. Two to three sprays of Mancozeb + Captan (0.2%) or Thirum + Carbendazim (0.2%) or Propiconazol (0.1%) should be taken to reduce the grain mold in soghum. Pre-harvest foliar spray of Mancozeb (0.25%) also reduced the grain mould. Spraying with talk based formulation of Pseudomonas (0.2%) two times increase the seedling growth and reduce the grain mold in sorghum. In case of kodo poisoning, treat the infected grains with cow dung before consumption

Phanerogamic plant parasite: A partial root parasite popularly known as witch weed (*Striga* spp.) is a very serious problem in majority of millets including sorghum, pearl millet, kodo millet and finger millet in light and low fertile soils... Three species of Striga namely *S. asiatica, S. hermonthica* and *S. densiflora* have been reported to attack the millets and produces a variety of debilitating symptoms like increase in the host root:shoot ratio, and reduction in photosynthetic efficiency. It damages its hosts by withdrawal of water, nutrients and assimilates. Infestation of Striga establishes the close biological association with host plant and inhibits the normal growth resulting devastating yield loss.

The weeding or hand pulling of Striga plants before flowering is the cheapest and effective method for its eradication. Application of nitrogenous fertilizers also reduces the infestation of Striga species. Soil application of 100% RDF is best for Striga management in kodo millet. Soil application of farm yard manure (FYM) + vermi-compost (VC) enriched with Trichoderma + Azospirillum @ 2 kg/tones of manure and application of FYM + VC enriched with Trichoderma @ 2 kg/tones of manure before sowing is also effective to minimize the infestation,

Emerging diseases of millets

Banded leaf and sheath blight: Banded leaf and sheath blight (BLSB) caused by Rhizoctonia solani is an emerging soil borne disease of all the small millets. The disease is characterized by oval to irregular light gray to dark brown lesions on the lower leaf and leaf sheath. The central portions of the lesions subsequently turn white with narrow reddish brown margins. Under favourable conditions, lesions enlarge rapidly; coalesce to cover large portions of the sheath and leaf blade. At this stage, the disease symptoms are characterized by a series of copper brown colour bands across the leaves and sheath giving a characteristic banded appearance. In severe cases, irregular to oval dark brown to purplish brown necrotic lesions appear on peduncles, fingers and glumes. The white mycelial growth along with sclerotia of the fungus can be observed on and around the lesions.

Clean cultivation, draining out of excess water, removal of grass weeds and use of resistant cultivars can prevent the disease. One spray of Propiconazole @ 1 ml/litre of water are cost effective against BLSB in finger millet. Seed treatment with Validamycin or Hexaconazole @ 2ml/lit. of water + 1 FS of same fungicide is very effective against BLSB in kodo millet and little millet. One foliar spray of Salicylic acid or Sodium fluoride @ 200 ppm induced the resistance against BLSB in kodo millet & little millet. Soil application of FYM/VC enriched with Pseudomonas fluorescence + *Trichoderma viride* + *Bacillus subtilis*or only *T. viride* @ 2 kg /t of manure is very effective.

Foot rot of finger millet: Foot rot of finger millet caused by *Sclerotium rolfsii* is a soil borne sporadic disease observed in all finger millet growing areas. The infection occurs in and around the collar region restricted to 2-3 inches above ground level. The basal portion of affected plant appears water soaked that turn brown with a concomitant shrinking of the stem in the affected region. Profuse white cottony mycelia growth occurs in the affected areas with small global white velvety mustard seed like sclerotial bodies. Finally the leaves lose their luster, droop, dry and the plant dries up prematurely. Sandy loam soils, low soil moisture and warm humid conditions favour the disease development.

Use of resistant varieties is the best cost effective management option. Soil treatment with Vitavax @ 10 kg /ha is effective against foot rot of finger millet. Soil application of *Trichoderma viride* + Pseudomonas fluorescence 500 g each mixed with 25 kg compost incubated for 15 days and spread over an acre at the time of weeding results least foot rot incidence and higher yield.

Narrow leaf spot of finger millet: The disease caused by *Cercospora eleusinis*and appears in June in early sown crops. Disease is restricted to cooler regions, where mean temperature does not exceed 200 C. The disease can occur during all stages of plant growth from seedling to grain filling. It disease occurs immediately after heading, it can reduce the yield up to 40%. Reddish brown speaks with yellow halo are formed on leaves. Symptoms also produced on stem, leaf sheath and fingers. Delayed sowing in the month of July decreases the disease incidence and severity. Foliar spray of carbendazim (0.05%) reduces the disease incidence.

Leaf blight of little millet: Leaf blight caused by *Alternaria alternata* is one of the emerging disease of little millet and first time observed from Bengaluru on little millet cultivar VS 13 during 2018. Up to 53% disease incidence was recorded. The characterisitc symptoms of the disease were formation of dark brown, circular to oval necrotic spots surrounded by concentric rings on upper leaf surface of little millet. As the disease progressed, infected leaves become blighted. The pathogen could be efficiently suppressed by fungal bioagent *Trichoderma harzianum* and bacterial bioagent Bacillus velezensis.

Leaf blight of browntop millet: Leaf blight of browntop millet caused by Bipolaris setariae was first time recorded during 2018 from Bengaluru and about 75% plant were found infected. Initial symptoms were formation of minute brown lesions (1-5 mm) with small halo on the adaxial side of the leaves. Afterwards, spots were coalesced and leaves become blighted.

Sheath rot of kodo millet: In some part of Tamil Nadu, kodo millet is taken as rabi/summer crop after paddy and sheath rot caused by *Sarocladium oryzae* is of very common

occurrence. The disease reduces grain yield and grain quality by retarding or aborting panicle emergence resulting unfilled seeds and sterile panicles.

Reappearance of diseases

Udbatta: Udbatta caused by *Ephelis oryzae* is a seed borne panicle disease commonly observed on foxtail millet, kodo millet and little millet. It is a minor disease of small millets and reported in paddy growing areas (1931). The disease was reappeared in kodo millet in sporadic way during rainy season of 2008 and in foxtail millet during 2013. Infected plants are usually stunted and occasionally narrow stripes are formed on the flag leaf along the veins. Affected panicles are transformed into a compact silver coloured cylindrical spike that looks like an incense stick resembling an Agarwatti. Hence, the name Udbatta. Infected panicles fail to produce normal grain and become sterile.

Removal & burning of affected panicles, Keeping bunds & field free from graminaceous weeds, Seed treatment with Carbendazim @ 2 g/kg seed

Leaf blight of kodo millet: Leaf blight of kodo millet caused by Alternaria species was reported for the first time in India from Kanpur during 1980. The disease reappeared in a moderate to severe form on kodo millet at Karnataka and M.P. during 2013. Pale and straw coloured small scattered lesions are formed on the leaf blade. Severely affected plant showed a blighted appearance causing premature drying of leaves from tip to downward.

Grain smut of foxtail millet: Grain smut of foxtail millet caused by Ustilago crameri has been reported earlier from Karnataka, A.P., T.N. and Maharashtra. During 2010, the disease was recorded from Tehri Garhwal (UK) in a severe form and 75% disease incidence was recorded in cultivar RAU 2 followed by 60% in PS 4 and TNAU 264. The fungus affects most of the grains in an ear but sometimes terminal portion of the spike may escape, producing smut sore in flowers and basal portion of the palea. After the rupture of sori dark black powdery mass of spores could easily be seen on the infected ear heads.

Disease resistant/moderately resistant varieties of millets

Crop	Disease	Resistant sources
Sorghum	Anthracnose	CSH 1,2, SPV 1531, 1533, SPH 1148,1268 , CSV 17, CSV 31
	Ergot	CSH 3,6,9, GSH 1, CSV 4,10, CO 25, Swati ,CSV 17
	Grain mold	CSV 25, CSV 27, CSV 28, CSV 31
	Smut	CSH 9, SPV 102, 104, 115, 245, Jawahar Jowar 8, 1022,1041
	Leaf spots	CSV 17, CSV 18
	Charcoal rot	CSV 17, CSV 22, CSV 36, CSV 29R
Pearl millet	Downy mildew	WCC 75, ICM 7703, ICTP 8023, ISMV 155, RHB 233, RHB 234, HHB 299, ABH 1200Fe , ABH 1269Fe, HHB 311
	Ergot	HB 5, BD 763, MBH 110, PSB 8,JBB 4, RHB 233, RHB 234, HHB 299, HHB 311
	Long smut	Jawahar Bajra 2, MH 179, MBH 188, WCC 75, JBV 3, 4, RHB 233, RHB 234, HHB 299, HHB 311
	Blast	RHB 233, RHB 234, HHB 299, HHB 311

Crop	Disease	Resistant sources
Finger millet	Blast	GPU 28,GPU 45, GPU 48, OEB 10 (Chilika), OEB 526, OEB 532, PPR 2700 (Vakula), VL 315, VL 352, GN 5, GN 6, VL 149, VL 348, VL 379, PRM 1, VR 762 (Bharathi), Srichaitanya, KMR 301, KMR 340, KOPN 235, Dapoli 2, Vegavathi (VR 929), Birsa madua 3, CFMV 1, CFMV 2, CFMV 3 (Ekvijay)
	Brown spot	Vegavathi (VR 929),Birsa madua 3, Gowthami, CFMV 2
	Foot rot	Indaf 3, Indaf 6, Indaf 7, GPU 28, MR 6, GN 4 , PR 202 Vegavathi (VR 929), Birsa madua 3, CFMV 1, CFMV 2, CFMV 3 (Ekvijay)
	Banded leaf & sheath blight	GPU 28, VL 379, Vegavathi (VR 929), Birsa madua 3, VR 988,CFMV 1, CFMV 2, CFMV 3 (Ekvijay), Gowthami
	Smut	VL 149, GPU 28, GPU 45, GPU 67
Kodo millet	Head smut	JK 41, JK 48, JK 439, KK 1, KK 2, JK 106, JK 13, JK 65, JK 98, TNAU 86, JK 137, ATL 2, JK 9-1, CKMV 2
	Banded leaf & sheath blight	JK 13, CKMV 2, ATL 1
	Striga spp	JK 41, JK 155 and GPUK 3
Little millet	Grain smut	OLM 20, OLM 203 (Tarini), OLM 217, GNV 3, GV 2, JK 4
	Banded leaf & sheath blight	OLM 36 (Kolab), OLM 217, Chhatisgarh Sonkutki, CLMV 1, JK 95, GV 2
	Blast	GNV 3, OLM 203 (Tarini), JK 95, GV 2
	Rust	OLM 217, Chhatisgarh Sonkutki, CLMV 1, JK 95, GV 2
Foxtail millet	Blast	SiA 3085, RAU 2, SiA 3223 (Renadu), SiA 3088 (Suryanandi)
	Brown spot	RAU 2
	Banded leaf & sheath blight	RAU 2
	Downy mildew	SR 16 (Meera),SiA 3085, RAU 2, SiA 3223 (Renadu), SiA 3088 (Suryanandi)
	Rust	TNAU 196, RAU 2
Barnyard millet	Grain smut	VL 29, VL 172, VL 207, K1 , ER 64 (Pratap Sawan 1), TNAU 143
	Banded leaf & sheath blight	IIMRBM 8-1920, VMBC 335
Proso millet	Banded leaf & sheath blight	TNAU 202
	Leaf blight	PMV 442, TNAU 202, PRC 1, TNAU 143
Brown top millet	Leaf spot & blight	GPUBT 2, HBR 2
	Banded leaf & sheath blight	GPUBT 2, HBR 2

LEAD PAPERS

THEME-II

"CONVENTIONAL AND NATURAL FARMING APPROACH FOR MILLETS"

CONVENTIONAL AND NATURAL FARMING APPROACHES FOR MILLETS

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Introduction

Millets are traditionally being grown in rainfed conditions especially by the marginal farmers and tribals. Millets are among the oldest cultivated crops in India and rest of the world. Millets comprise two main groups of species, major millets includes Sorghum and pearl millets and the minor millets are represented by six cultivated species viz. Little millets, Indian barnyard millets, Kodo millet, Foxtail millets, Finger millets and Proso millet. Nearly 60 million acres of land in India are under millet cultivation. India is the largest producer of sorghum and millets, accounting for over 80% of Asia's production.

Natural farming is purported to be a disruptive farm practice addressing major concerns of farmers regarding rising cost of production. It envisages ecological or regenerative agriculture approaches under which the application of any kind of chemicals to soil biosystems is prohibited. It relies more on soil biology then soil chemistry by encouraging multi cropping, round-the-year soil cover, the addition of formulations made up of cow dung and urine to trigger the microorganisms in the soil system. Plants co-evolve with other organisms in the environment including microbes in a mutually beneficial relationship. This connection has been broken due to adoption of chemical based modern agriculture practices.

It is noteworthy to mention that against a fluctuating productivity trend in case of major food crops, millets have shown exceptional increase in productivity over the last five decades. Indian agriculture frequently suffers from the vagaries of monsoon, millets which are also known as "famine reserves" for their prolonged and easy storability under ordinary are of great relevance. They are most suitable for mixed and intercropping, thus offer sustainable resources use, food and livelihood security to farmers. Additionally, given the fact that millets are very good source of nutrients, developing countries like India which reports dramatic rates of malnutrition (around one fifth of the population) particularly among children and women, promotion of millets farming can help in fighting malnutrition. National Council of Applied Economic Research (NCAER) report in the year 2014 has revealed the exponential drop in the consumption of hardy millets from 32.9 kg in 1960 to 4.2 kg in 2010 since urbanisation made Indians switch to wheat and rice. Cultivated as dual-purpose crops (food & fodder), millets contribute to the economic efficiency of farming and provide food/livelihood security to millions of households, particularly the small/marginal farmers and the inhabitants of rain fed/remote tribal regions. Research says that a 1% productivity increase could reduce poverty by 0.65% (National Centre for Agricultural Economics and Policy Research Report, 2011). Increasing productivity is more important in rainfed areas as these are 30% less productive than irrigated areas. It seems that millets could be the answer to fighting climate change, poverty and malnutrition.

Organic farming for millets

Organic farming and millet cultivation were common practices in India for millennia. But we've forgotten about them in the past few decades. It's time to reintroduce them to society.With climate change wreaking havoc on agricultural land through increased temperature and water shortage, and the chemicals used in conventional farming practices only compounding the problem, sustainable organic farming and millet cultivation is the need of hour to produce food without harming the environment.

The Green Revolution of the sixties heralded a new era for agriculture in India. The need for large-scale food production was met by using high-yielding varieties of wheat and rice and implementing modern farming methods, which entailed the extensive use of chemical fertilisers and pesticides. While the movement helped India meet its high demand for food, the practices it popularised had resulted in second generation problems and a severe deteriorating impact on the environment.

With droughts becoming more commonplace in some of India's most prominent agricultural regions, the country's farmers need to adopt farming practices, which have the least impact on the environment while still producing a large enough quantity of crops to sustain their livelihood and the country's food demand. That's where sustainable organic farming and millets cultivation come into play.

Millets are climate-smart and can be grown in drought-hit, arid regions more successfully than any other crop. They also have an extremely low water footprint, with a crop of millets requiring around 80 percent less water than crops like rice, wheat, or sugarcane. Further, millets are excellent for soil conservation by maintaining soil structure and retaining water due to their root network, thus preserving soil health for extended.

Natural farming of millets & climate change

Organic farming may address both emissions avoidance and carbon sequestration. Natural farming also improves overall resilience of crops to adverse climatic conditions and improves energy and water efficiency. It also has the potential to reduce carbon emissions. The studies highlight that natural farming practices can help prevent over-extraction of groundwater, enable aquifer recharge and contribute to increasing water table.

Importance of organic and natural farming of millets for soil health

Healthy soils are the basis for healthy food production. And the AI-NPOF project shows that the organic approach is better at ensuring soil macro- and micro-nutrients, organic carbon and rhizospheremicrobiome. While mean organic carbon is highest in 91 per cent cropping systems with organic approach, macronutrients like nitrogen, phosphorus and potassium are higher than inorganic approach in 42 per cent cropping systems. Though the integrated approach led to better results than inorganic in all cases, suggesting that lesser chemicals lead to better results in sustainability parameters, AI-NPOF results show that organic is even better than integrated in all except the cases of potassium, iron, manganese and bulk density. Macro and micro nutrients, soil organic carbon, soil enzymes, earthworms, soil respiration and microbial biomass increase after adoption of natural farming and Zero Budget Natural Farming (ZBNF).

Suitability of millets for natural farming

The Centre for Science and Environment (CSE), a Delhi-based non-profit, has recently consolidated long-term evidence on holistic benefits of organic and natural farming. In the report, Evidence (2004-20) on Holistic Benefits of Organic and Natural Farming in India, they state that organic and natural farming are not only profitable and sustainable but also productive when compared with the chemical-dependent inorganic farming. Evidence collated by CSE from other scientific studies further adds to this evidence. These studies have found that in crops such as ragi and pearl millet yields can be higher with organic and natural farming in comparison to inorganic. In case of natural farming, crops like finger millet and jowar (sorghum) also show higher yields.

Crop diversification through millets

Organic & natural farming is an option. Rice and wheat are an integral part of the Indian population's staple diet, and replacing them entirely with millets is neither viable nor preferable. Millets are, however, the ideal crop for cultivation during fallow periods—the time between the cultivation of one batch of crops and the sowing of the next. This is so because millets have a high tendency to form symbiotic relationships with mycorrhizal fungi. Millets have a lower yield per hectare than rice and wheat, making them less profitable than those popular crops for farmers. Farmers in possession of fertile lands that receive steady rainfall, for instance, have no reason to start cultivating millets as that would just reduce their profits. The low floor price of millets, caused by low consumer demand, prevents farmers from taking up millet cultivation. This problem is currently being tackled by several institutions and State governments which are taking several measures to increase the awareness and demand of millets.

Economics of organic & natural farming of millets

AI-NPOF project shows that the cost of cultivation is higher with the organic approach than integrated. The CSE report explains that the high-cost is because organic and bio-inputs used in AI-NPOF are largely purchased from the market. Whereas, organic inputs cost is less if produced on-farm by farmers. Despite high cost of cultivation at AI-NPOF's farms, net returns are highest in 63 per cent of cropping systems with organic approach. Similarly, in the case of integrated approach, net returns are highest in 11 per cent cropping systems.

Other scientific studies suggest that in the case of natural farming, yields may not always be high for all crops, but the benefit-cost ratio is several times higher than inorganic. Along with minimised cost of production and premium prices for the produce, incomes and profits under natural farming are higher than conventional farming.

On an average, even without certification, produce from natural farming fetches higher the income of conventional farming, suggest the studies. Moreover, they, say use of cheaper eco-friendly biofertilisers also makes organic farming a low-cost alternative to chemical methods.

Way forward for organic & natural farming of millets

It is important that the country's larger scientific community, trained in chemical-based agriculture, does not out rightly reject the evidence due to any bias and instead carefully review results of the work done by its scientific colleagues in different parts of the country. The work is

scattered and followed compartmental approach rather than holistic approach. They can play a crucial role in spreading awareness, building capacity and influencing policymakers. It is also important that the advantages of organic and natural farming should not be evaluated only on the basis of yield.

The existing programmes to support organic and natural farming should therefore be scaled up, expanded and properly funded for better foundation learning, critical thinking and experiential learning by the scientific community and other stakeholders.

Policies for adoption of agro-ecological approaches across different parts of the country in view of its holistic benefits such as nutrition, livelihood of farmers, natural resource conservation, biodiversity, resource efficiency, soil-health, disease resilience and mitigation of climate crisis.

Mechanisms for incentivising farmers to adopt agro-ecological practices such as payments for ecosystem services, and specifically focus on supporting farmers during the transition to organic and natural farming through technical and financial support.

Support systems to adequately produce and make available quality organic fertilisers and biofertilisers at low cost should be the priority.

The natural farming certification process should be improved to make it farmer-friendly and low cost. Measures should be taken to address concerns about PGS-India (Participatory Guarantee System of India) certification system and its implementation. They can be instrumental in helping farmers sell organic and natural produce by developing Niche areas identification for developing value chains and developing systems for procuring produce and getting remunerative prices of millets should be developed.

Suggested readings:

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MAINSTREAMING MILLETS IN FOOD PLATES OF ALL: ISSUESAND PROSPECTS AFFECTING PROFITABILITY, SUSTAINABLE LIVELIHOODS, CLIMATE RESILIENCE AND FOOD & NUTRITION SECURITY

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Introduction

ICAR-Indian Institute of Millets Research and National Agricultural Systen has pioneered research and Development efforts on millets improvement, value chain modelling, capacity building, and entrepreneurship development and has admirably supported the Government of India's Plan through DAC&FW in designing and implementation of the sub-Mission on Nutricereals under NFSM. Keeping in view the efforts of ICAR-Indian Institute of Millets Research in creating an ecosystem to create demand for millets, now millets are gazetted by Government of India as "Nutri-Cereals" for their superior nutritional characteristics compared to fine cereals such as rice and wheat. Success of Green Revolution had created food sufficiency, but the focus now now is on nutrition security which is the need of the hour. The efforts over the last decade in the diversification of millets and promotion of their nutritional richness, millets are again being rediscovered as the climate resilient alternate nutria-rich staples supplementing Rice, Wheat and Corn in the global front to usher in Nutrition Security. In response to the UNGA's declaration of 2023 as the International Year of Millets, the efforts for mainstreaming the millets both nationally and globally have started with ICAR, DARE and the Department of Agriculture Cooperation and Farmers Welfare, Government of India. India is the world's leader in the production of millets with a share of around 40% of the world's total production. India produces around 16 million MT of Millets annually (Source: DAC& FW). India is the second largest exporter of Millets. Millets exports from India have continuously increased at 12% CAGR in the last 3 years. The millets market is set to grow from its current market value of more than $9 billion to over $12 billion by 2025. IIMR has been working with diverse range of stakeholders during the efforts for piloting the value chain interventions, especially under the NAIP sub project undertaken by IIMR led consortium. IIMR's Technology Business Incubator is supporting and nurturing entrepreneurs and startups across the country by vetting ideas from early-stage entrepreneurs and start-ups. Nutrihub provides last mile connectivity with Consumer and it leverages technology generation from Centre of Excellence on millets and offers Infrastructure for production of value-added products as startup facility and mentoring, R&D support, Training, Market facilitation and industry and government market connectivity. The millets' market is projected to grow from its current value of more than $9 billion to over $12 billion by 2025, based on current trends and extrapolation. ICAR-IIMR and APEDA have been organizing sensitization events to educated millet startups on value addition, emerging trends, and potential export markets. Thus, a framework is put in place to work on the refinement of the value chain for export markets, with the involvement of several other stakeholders such as ICRISAT, NIN, IIFPT, DFRL, CFTRI, Private companies, FPOs, etc. Scaling up the Value

Chain on Millets may be achieved by replicating the pioneering efforts by ICAR- Indian Institute of Millets Research which has paved a pathway for reviving millets in the country through addressing backward integration related to supply chain, retrofitting processing machinery, diversification of processing technologies for bringing the convenience and increasing shelf-life, nutritional evaluation, awareness creation, commercialization for proving consumer acceptability, Entrepreneurship development, Involvement of private sector through niche markets, etc., for transforming the traditional crops grown for farmers' "domestic consumption" to an emerging role as "commercial crop". ICAR-IIMR being pioneers in the development of the value chain on millets can bring all the stakeholders such as R&D institutes, farmers, FPOs, private food processors, state, and central government departments on board in delivering the outputs that are needed for envisioned millets promotion in the domestic market by effectively capturing and aligning the efforts with the consumer preferences in terms of emerging food trends.In the light of growing importance of millets across the globe and the declaration of IYOM 2023 by UNGA, it is imperative of India to take lead in mainstreaming the millets to bring them on the common man's plate by building a sustainable value chain in millets to usher the millet exports and enhance the demand at domestic and international levels. In this connection, we would like to propose an upgradation of ICAR-IIMR into a "Global Millet Hub for R&D" for Showcasing and replicating successful and sustainable Millet value chain for other countries through capacity building, skill development and strengthening stakeholder linkages and linking farmers to markets

Millets belong to the food group of coarse cereals, primarily categorized as major and minor/small millets. The nutritional superiority of the millets to the regular staples like wheat and rice has entitled them to be called as nutricereals. Ecologically, millets are an important crop owing to their short growing season, malleability to adapt to a wide range of temperature, moisture-regime and input condition.The commonly cultivated species of millet in India include Sorghum, Pearl millet, Finger millet, Foxtail millet, Kodo millet, Proso millet, Barnyard millet and Little millet. These are cultivated under rainfed conditions. The growing habitat as well as the amount of rainfall in the region plays an important role in the geographical distribution of millets either as primary or allied crops. Usually, the millet crops are cultivated in combination with pulses, oilseeds, spices and condiments.

A. Status of area, production and productivity of millets in India

Despite the ease of cultivation, there has been a downward trend in the cultivation of millets. In India, production of sorghum came down from 7.0 million tonnes during 2010-11 to 4.2 million tonnes during 2015-16, bajra production has reduced from 10.4 million tonnes to 8.1 million tons, production of ragi reduced from 2.2 million tonnes to 1.8 million tonnes while production of small millets came down to 0.39 million tonnes from 0.44million tonnes during the same period (DayakarRao et al, 2018).

Area under sorghum has declined from 7382 thousand hectares in 2010-11 to 4480 thousand hectares in 2018-19 with an average compound growth rate of -5.13 percent while the area under pearl millet (-2.85%), Ragi (-2.77 %) and small millets (-6.01%) has also witnessed a declining trend. Production of all the millets recorded high negative growth rate (-3.23 %) which might be due to a decrease in area and shift to other crops. Though there is a decline in area and production, at the overall level, the yield has shown a growth with a CAGR of 0.31 percent, in

the last eight years. Also, in Bajra and small millets, the yield has witnessed a growth with a CAGR of 1.28 percent and 4.34 percentrespectively.In spite of all the extraordinary qualities and capacities of millet farming systems, the area under millet production has been shrinking over the last five decades and rapidly, since the Green Revolution period due to relentless promotion of other crops such as rice and wheat for intensive farming in select few resource rich areas under irrigated conditions.

1. Millets Production scenario in India

A total of about 15.3 m tonnes of millets food grains are produced in India from nearly 12.7 million ha area, which constitutes about 6 % of the national food grain basket. Pearl millet is grown in about 6.77 million hectares yielding 8.9 million tonnes, followed by sorghum (4.48 million ha, yielding 4.38 million tonnes) and finger millet (0.97 million ha, yielding 1.68 million tonnes) and other millets (0.46 m ha yielding 0.34 million tonnes).

Despite the surrender of almost 56% area, the millet production has increased from 11.3 to 15.3 million tonnes during the last 50 years due to an increased productivity that went up by more than two times overall while it's more than tripling in pearl millet. Development and adoption of improved varieties/hybrids have played a significant role in the productivity improvement of these crops.

During the past 5 years (2014-19), millets were annually cultivated in an area of 13.7 m ha producing 15.26 m ton of grains in the country. With the promotion of millet cultivation in various states during 2019, the decline in area has been arrested with slight uptrend. During 2019-20, the area under millet crops was about 12.68 m ha compared to 12.25 m ha during 2018-19. Though the area decreased by 20% compared to previous five years (2009-13), production decrease was only 12.7%, due to 9.1% increase in yield. During the past 5 years, though the area under the millet crops in the country has been on a declining trend, but the productivity has been gradually increasing. Yield levels increase by 8.4% in 2019-20 compared to the preceding year.

Millet crops area, production and yield during 2009-13, 2014-19 & 2019-20

	Area (000 ha)			**Production (000 ton)**			**Yield (kg/ha)**		
	2009-2013	**2014-2019**	**2019-20**	**2009-2013**	**2014-2019**	**2019-20**	**2009-2014**	**2015-2019**	**2019-20**
Sorghum	6684	4910	4480	6101	4404	4380	913	897	1051
Pearl millet	8480	7142	6770	9029	8738	8900	1065	1223	1265
Finger millet	1211	1104	970	1914	1710	1680	1580	1549	1662
Small millets	773	570	460	428	403	340	554	707	804
Total millets	**17149**	**13726**	**12680**	**17472**	**15255**	**15300**	**1019**	**1111**	**1236**

(Based on estimations of Dept. of Economics & Statistics, DAC&FW, GoI, New Delhi)

Per cent change in area, production and yield of millets during last five years (2014-15 to 2019-20)

Crop	Area	Prodn.	Yield
Jowar	-17.8	3.3	35.1
Bajra	-7.5	-3.1	0.9
Ragi	-19.8	-18.4	-2.4
Small millets	-22.0	-11.9	22.9
Total millets	-13.0	-3.6	13.5

2. Statewise Area, Production and Productivity of Millets in India

Rajasthan, Maharashtra and Karnataka are the top most states of millets cultivation in the country with share of 34 percent, 24 percent and 13 per cent to total millets area. Rajasthan, Uttar Pradesh, Karnataka and Maharashtra tops in production which contributes 28, 14, 14 and 13 percent to total production. However, highest yields were recorded in Gujarat (2005 kg/ha), Uttar Pradesh (1826kg/ha) and Madhya Pradesh (1794 Kg/ha). In case of sorghum cultivation, Maharashtra, Karnataka and Rajasthan are the top most states. Rajasthan, Maharashtra and Uttar Pradesh were the major states which grow bajra. The area under ragi is more in Karnataka followed by Uttar Pradesh and Maharashtra. Madhya Pradesh, Tamil Nadu and Maharashtra tops in small millets cultivation in the country.

Causes for decline of area: The main reasons for decline of the millets crops in India are low remuneration as compared to other competing crops, lack of input subsidies and price incentives, subsidized supply of fine cereals through PDS, and change in the consumer preferences (NAAS, 2013). These factors had led to shift from production of millets (jowar in particular) to other competing crops such as soybean, maize, cotton, sugarcane and sunflower in the country as a whole. In the context of present Indian agricultural scenario the production and income increase of the farmers through area expansion is of major limitation, since supply of area is inelastic in nature. To achieve the target of doubling the farmers' income by 2021-22 the policy makers also need to address issues other than area expansion. Generation of demand for the millets-based products along with productivity enhancement would help the farmers in realising better prices for their produce. Since the processing of millets involve significant hardships as compared to the rice and other foodgrains, proper processing and value addition will be effective in creating more demand among the consumers.

B. Gaps identified for enhancing production and productivity of millets and way forward to fill the gaps

Compared to wheat, rice and maize, millets have lower productivity which is attributed to their cultivation in marginal lands in rainfed farming and to non-adoption of improved cultivars. The yield gap is largely a reflection of farmers' cultivation methods that offer ample room for improvement. The grain yield gaps as documented in the recent FLDs vary from 40 to 92% in various millets and 38-40% for stover yield in sorghum.

To abridge the yield gaps of sorghum and pearl millet, considerations are:

i) Variety, soil fertility and weed management are the predominant causes of yield gaps,

ii) Great potential exists for closing the yield gap by improving agronomic practices,

iii) Integrated watershed-based approach encompassing harvesting of excess rainfall for supplemental irrigation,

iv) Integrated nutrient management(INM), integrated pest management (IPM) and integrated disease management (IDM) would be essentially required,

v) Value addition of products and their multiple uses are necessary to make them more remunerative for the farmers.

The largest yield gap for bajra is in Rajasthan which may be due to poor soil fertility and wide rainfall fluctuations. Overall wider yield gaps show a significant scope for yield improvement of sorghum during kharif season with the adoption of improved cultivars and technologies through a well-planned strategy in Central India. The application of protective irrigation at flag leaf and grain filling stage could boost the productivity of sorghum.

In small millets, availability of seeds of improved varieties is the key to increase productivity. Since in many areas these are grown without fertilizers and plant protection chemicals, their end-use as organic foods would fetch higher returns for farmers.

Thus, to bridge the yield gap in millets, there is need to make available quality seeds, hybrids, enhancing seed and varietal replacement and strengthening community seed systems; vertical expansion-increased productivity through trait led genomics; all season sorghum cultivars, short duration hybrids with erect leaf ideotypes for high density planting and product diversification in pearl millet for demand led infusion; horizontal expansion in non- traditional states; incentivising cultivation; need for better agronomy and watershed development.

Other important criteria for yield enhancement include:

i) Improving the availability of seed to the farmers – seed hubs and PPP mode,
ii) Pre-breeding activities to incorporate resistance to blast,
iii) Physiological breeding,
iv) Enriching genomic resources for modernizing the breeding activities,
v) Utilization of speed breeding technology for rapid genetic advancement in parental line development in public sector institutions,
vi) Input use efficiency through agronomic management;
vii) Benchmarking of nutritional traits – already done in millets

C. Enhancing Seed production

The hybrids developed in sorghum and pearl millet in 1960s and onwards led to the birth and expansion of private seed industry in India. In the present hybrid seed market, 90% of the grain and forage pearl millet, 40-60% of grain sorghum and 70-80% forage sorghum are catered by private hybrids and the rest by public sector hybrids. Hitherto the quality seed production has been almost non-existent in other millets except for kharifjowar and bajra, and to some extent in ragi.

State/UT	Area ('000 Hectares)					Production ('000 Tonnes)					Yield (Kg./Hectare)				
	2015-16	2016-17	2017-18	2018-19	2019-20	2015-16	2016-17	2017-18	2018-19	2019-20	2015-16	2016-17	2017-18	2018-19	2019-20
Andhra Pradesh	293.00	202.00	244.00	223.00	236.00	505.00	329.00	453.67	301.91	514.19	1724	1629	1859	1354	2179
Arunachal Pradesh	27.50	5.28	26.77	26.78	26.76	27.56	27.03	27.30	27.39	27.43	1002	5118	1020	1023	1025
Assam	6.60	4.75	5.23	5.21	5.21	4.45	2.93	3.06	3.06	3.23	674	616	584	587	619
Bihar	12.79	11.54	12.99	15.31	7.96	15.87	10.60	12.46	13.61	7.32	1241	918	959	889	920
Chhattisgarh	101.70	95.60	94.30	94.01	69.10	16.30	26.94	22.34	30.28	20.49	160	282	237	322	297
Gujarat	533.00	578.00	513.00	480.37	496.07	960.75	1136.00	1116.23	1000.15	990.48	1803	1965	2176	2082	1997
Haryana	423.00	540.00	498.00	465.00	522.70	680.00	997.00	745.81	899.56	1034.90	1608	1846	1498	1935	1980
Himachal Pradesh	6.15	7.85	5.99	6.82	7.08	5.03	6.31	5.28	5.95	6.81	817	804	881	872	961
Jammu & Kashmir	14.97	31.27	18.87	29.34	17.70	7.68	15.57	10.56	15.29	5.82	513	498	560	521	329
Jharkhand	16.62	26.98	22.96	16.20	16.67	10.58	22.99	21.04	12.77	14.31	637	852	917	788	859
Karnataka	2003.00	1809.00	2131.00	1673.71	1838.60	2298.18	1966.97	2739.07	1762.17	2555.60	1147	1087	1285	1053	1390
Kerala	0.26	0.18	0.28	0.48	0.56	0.22	0.16	0.27	0.47	0.54	850	868	936	992	971
Madhya Pradesh	653.00	686.60	728.00	491.00	487.89	1092.26	1173.15	1469.12	851.34	895.71	1673	1709	2018	1734	1836
Maharashtra	4187.00	4064.20	3154.30	2368.10	3086.56	1809.26	3126.02	2403.02	1319.31	2428.70	432	769	762	557	787
Meghalaya	2.91	2.94	2.92	2.90	2.89	2.76	2.81	2.78	2.74	2.72	950	956	951	945	941
Nagaland	10.01	11.31	11.83	10.16	10.17	11.07	12.40	13.00	11.30	11.31	1106	1096	1099	1112	1112
Odisha	79.36	81.69	79.15	78.79	76.44	46.21	51.54	52.25	48.18	48.07	582	631	660	611	629
Punjab		1.20	1.00	1.10	0.50		0.70	0.60	0.72	0.32		583	598	651	635
Rajasthan	4675.76	4729.62	4752.33	4744.59	4930.01	3871.56	4504.51	4054.20	4277.73	5141.65	828	952	853	902	1043
Sikkim	6.42	6.65	2.47	2.11	2.28	6.47	6.71	2.55	2.18	2.37	1008	1009	1031	1032	1037
Tamil Nadu	512.04	402.97	560.44	533.58	627.88	917.29	391.78	926.68	873.47	1017.03	1791	972	1653	1637	1620
Telangana	84.00	109.00	77.00	65.00	100.00	83.00	105.00	83.67	72.25	139.15	988	963	1087	1112	1392
Tripura	0.10	0.86	1.10	0.83	0.74	0.08	0.69	0.89	0.67	0.61	820	800	812	800	817
Uttar Pradesh	1138.00	1099.00	1103.00	1030.00	1093.00	1885.00	1924.00	2014.98	1967.27	2171.91	1656	1751	1827	1910	1987
Uttarakhand	166.45	170.00	162.00	148.00	137.00	224.89	245.00	216.80	179.74	191.09	1351	1441	1338	1214	1395
West Bengal	13.48	12.46	14.94	8.83	9.20	14.23	12.99	15.84	7.60	9.83	1056	1043	1060	860	1068
D & N Haveli	0.85	0.87	0.86	1.20	0.91	1.62	1.47	1.46	1.56	1.50	1900	1703	1703	1302	1653
Delhi	4.76	4.69	4.64	4.64	4.63	6.93	6.34	6.29	6.29	6.24	1455	1352	1355	1356	1349
Daman & Diu	0.43	0.43	0.43	0.50	0.33	0.59	0.48	0.58	0.65	0.37	1369	1101	1333	1306	1150
Puducherry	0.01	0.07	0.13	0.12	0.18	0.02	0.07	0.36	0.28	0.42	2429	1075	2820	2339	2358
All India	**14994**	**14718**	**14246**	**12543**	**13829**	**14517**	**16125**	**16436**	**13711**	**17261**	**968**	**1096**	**1154**	**1093**	**1248**

1. Seed availability

Farmer saved seed and local land races predominate the seed scenario except in bajra and sorghum where hybrids are popular. In ragi also major area is taken by improved varieties. In other millets, improved varieties have hardly made a mark.

Percent seed market for top Hybrids in seed production*

Hybrid	Developed by	Per cent seed market share
Sorghum		
CSH 14	Public Sector	15
CSH 9	Public Sector	12
CSH 16	Public Sector	15
JKSH 22	JK Agrigenetics	20
MLSH 296	Crystal Crop	15
HTJH 3201	Hitech Seeds	23
Pearl millet		
HHB 67 improved	Public sector	10
PROAGRO 9001	Bayer	20
KAVERI SUPERBOSS	Kaveri seeds	15
86M38	Corteva	15
DHANYA (MP 7933)	Metahelix	15
86M90	Corteva	25

*Estimates based on market sources

Area Under Hybrids*

Millet crop	Hybrids	Varieties
Sorghum	60%	40%
Pearl millet	85%	15%

*Estimates based on market sources

The varietal seed requirement (excluding the farmer-saved seed), is almost fully catered by public varieties produced by ICAR institutes and SAUs. This constitutes of about 40-60% of sorghum seed market, 10-15% of pearl millet varieties/ composites and 100% of all other millets. Seed production in millet crops by public agencies including state and national seed corporations is about 70 to 85 thousand quintals each year.

In small millets, state-specific varieties are common, since the area under these millets has shrunk to few pockets. Moreover, most of the improved varieties are not in seed chain as there is no significant demand for quality seeds from states. Therefore, the national average yields of small millets have not increased in commensurate with release of new varieties.

2. Measures to enhance availability of improved seeds

A major input for enhancing farm productivity in terms of production of millets is the adoption of high yielding and climate change resilient varieties to both replace older varieties/land races and area expansion. Current availability of quality seed of improved varieties is limited in all millets except in bajra where private hybrids form bulk of the seeds planted. In order to improve the availability of quality seeds of all millet crops across the states where they are grown, 24 state-centric seed hubs have been sanctioned under NFSM Sub-Mission on Nutricereals, to cater to 10% increase in availability of quality seeds each year. These seed hubs would source the quality breeder seed from breeder seed production (BSP) centres which are being supported under this mission. The breeder seed and seed hub centres are being brought together to enhance availability of quality seed with the coordination by the ICAR-Indian Institute of Millets Research.

3. Enhanced Breeder Seed Production (EBSP)

Provision of quality seed – Breeder seed and certified seed production of latest high yielding varieties to enhance the seed replacement ratio in millets- Breeder seed production and Seed hubs have been initiated. Due to the sanction and functioning of 18 EBSP centres under the DA&FW sponsored NFSM Sub-mission on nutricereals, additional 751, 852 and 1140 quintals of breeder seed were produced during 2018-19, 2019-20 and 2020-21 respectively, in millet crops. This can provide quality seeds for additional 10% area. The quality seed to farmers' is provided at subsidy to farmers, reducing the cost of production and increasing productivity. Except pearl millet where private hybrids are predominantly cultivated, in all other millets recently released (up to 10 years old) cultivars are brought in seed production chain, thus trying to augment productivity in farmer's cultivation. However, some golden varieties are also in seed chain due to their unique traits such as adaptation, culinary properties and broader resistance to pests and diseases, etc.

4. Millets seed hubs

During 2019-20, DA&FW also sanctioned 25 seed hubs for millets to fill the quality seed supply gaps. The quality seed forms the vital input for farming and it is therefore, necessary that extra care is taken and sufficient funds are to be allotted for seed hubs to initiate and sustain large scale quality seed-multiplication programme. This functional component of seed hubs is aimed at rapid multiplication of new and latest varieties notified and made available to seed minikits and other state programmes, besides to farmers. Most of the foundation and certified seed production is taken up by the universities/ICAR institutes/KVKs in farmers' fields with agreement and buy back, besides on their own farm or /leased lands. Besides providing substantial inputs, they have to follow up requisite operations, like pollinations, isolation, roguing, processing, etc., before the seed is ready for distribution by the mission and other programmes. Some seed hub centres were operational during 2020-21 and could produce only 2872 q against the target of 5851q.

5. The gaps observed in existing millet seed hubs

Seed hub model in millets was however not successful so far due to non-provision of revolving fund for seed production and/ or buyback from seed growers through farmers participatory seed production. Revolving fund was an integral part of seed hubs on pulses which

was largely successful. Revolving fund was also provided for oilseeds seed hubs. Moreover, six major millet seed hubs in major millets growing states of Maharashtra, Karnataka, Telangana, Odisha, etc. were not provided any funds whatsoever on the pretext that they were already having pulses/oilseeds seed hub though their expanded physical capacity for production and storage were limited to pulses/oilseeds seed production only. This impacted the set goals for seed production in millets seed hub. Therefore, provision of revolving fund for seed production is indispensable without which the set objectives will not be fulfilled. Also the six seed hubs which were not provided any assistance need to be provided dedicated resources for quality seed production in millets.

Once the quality seed must be available on a mission mode, adoption of HYVs of these millet crops will significantly add to the development of the dryland agriculture in the country. Foe achieving the same, following are necessary.

- Linking of EBSP centres and seed hubs with state and national seed corporations to improve synergies for quality seed production in millets
- Developing a robust seed system for states to increase the area and production of millets (including small millets) may be taken up on priority basis
- There is a need to improve the varietal replacement ratio with current 35 % of the varieties to higher levels with additional focus on including the small millets in seed value chain.
- National Seed Corporation (NSC) to devise a plan along with ICAR-IIMR to utilize the farm facilities for seed production (including multiplication) and plan for distribution of minikits to hasten production and multiplication of certified and foundation seeds.

D. Crop improvement

Crop improvement programmes at IIMR and centres of AICRPs on millet crops have been working on the enhancement of productivity of these crops in view of the decreasing area, high nutritional value and the importance of sustenance of millets-based rural communities. Varieties for different needs such as short duration varieties, biofortified varieties, dual purpose types, varieties adapted to specific seasons and soil types, varieties tolerant to pests and diseases, varieties suitable for mechanical harvesting, etc. have been developed.Crop production technologies for efficient conservation and utilization of moisture, integrated pest and nutrient management, cultivation in rice fallows, summer production, etc. have been developed.

The yield potential of the newer varieties has been increasing over decades. New cultivars have been developed in all eight millets- 31 high yielding varieties and hybrids developed by ICAR and SAUs have been notified during last two years. Public sector cultivars notified at national level (recommended for multiple states) are available in all millet crops.

ICAR-IIMR identified suitable cultivars for specific-end products in collaboration with M/s Britannia Pvt. Ltd, for large-scale biscuit production. These cultivars have special features compared to market available grains. CSH 13 R was ideal for biscuit manufacture while CSV 15 and CSV 20 suited vermicelli and pasta making. Rabi sorghum varieties CSV 18, CSV 216R were suitable for popping, PhuleYashoda and C-43 were good for flaking. These cultivars have special features compared to market available bulk grains. Similar efforts for identifying other millets in line at the ICAR-IIMR.

Productivity enhancementcan also be achieved throughimplementation of Agro-climatic zone wise planning, Cluster approach, and wide extension of improved technologies such as seed, integrated nutrient management (INM), integrated pest management (IPM), input use efficiency and resource conservation technologies to the farmers and extension functionaries.

Numbers of Cultivars of millet crops notified during 2011-20

Millet Crop	No. of cultivars	National releases	Private sector	Public sector	Public Hybrids
Sorghum	39	16	7	32	5
Pearl millet	75	53	46	29	20
Finger millet	27	5	0	27	
Foxtail millet	6	3	0	6	
Barnyard millet	2	2	0	6	
Little millet	9	3	0	9	
Kodo millet	5	2	0	5	
Proso millet	5	2	0	5	
Total	**168**	**87**	**53**	**120**	**25**

Region-specific crop improvement is required in major millets. There is a need to identify the regions with reducing/reduced area under millets and create better profitability in millet cultivation through intensified breeding programs by creating HYVs like that of competing crops.

E. Area Expansion under millet crops

Bringing the additional lands under millets cultivation is another important factor in increasing the production, especially the fallow and wastelands and the non-traditional areas are more sustainable.Expansion of millets cultivation across the country by including non-traditional areas by leveraging ICAR network of millets coordinating centres can happen when farmers get higher share in the consumer rupee through value addition process. The possible options in this regard are briefed below.

1. Crop production in better endowed lands and non-traditional areas

Being a world's leading millet producer, we can augment higher production of millets from better endowed non-traditional regions of Punjab, UP, Bihar and other regions where ICAR has already initiated efforts to diversify agriculture by mainstreaming short duration millets in the Wheat-Rice cropping systems.

2. Bringing the fallow and waste lands under cultivation

Production of millets in India can be significantly increased through inclusion of fallow and waste lands in the country. The total waste and fallow lands in India has seen slow decline in the last decade and stands to be more than 36 million hectares during 2015-16. The target to bring the lands under cultivation of millets is fixed at 5%, 10%, 20% and 30% during next three decades.

Projected increase in production of millets in India with addition in areas from waste and fallow lands during 2022 to 2050

Area in '000 Ha Production in '000 tonnes		**2022**	**2030**	**2040**	**2050**
Component					
Waste Lands (Projected)		12111.28	12051.14	11991.31	11931.77
Total Fallows (Projected)		24391.35	24270.25	24149.74	24029.84
Total of Waste and Fallow lands		36502.63	36321.39	36141.05	35961.61
Total addition under millets		5% of total lands	10% of total lands	20% of total lands	30% of total lands
		1825.132	3632.139	7228.21	10788.48
Millets wise share	Sorghum	739.7276	1472.109	2929.601	4372.582
	Pearl Millet	867.7317	1726.847	3436.545	5129.224
	Finger Millet	138.5573	275.7387	548.7392	819.022
	Small Millets	79.11494	157.4443	313.325	467.654
Target Yield level (Kg. / Ha)	Sorghum	900	950	1000	1050
	Pearl Millet	1275	1300	1350	1400
	Finger Millet	1750	1775	1800	1850
	Small Millets	750	775	800	820
Additional output	Sorghum	665.7548	1398.504	2929.601	4591.211
	Pearl Millet	1106.358	2244.901	4639.336	7180.913
	Finger Millet	242.4753	489.4362	987.7306	1515.191
	Small Millets	59.3362	122.0193	250.66	383.4763
	Total	2073.924	4254.86	8807.327	13670.79

It has been estimated that an additional amount of 28 million tonnes of millets could be produced in the next three decades, if the waste and fallow lands are brought under cultivation of millets at above mentioned rates. This significant increase in the millets production can increase the income of dryland farmers in the coming years. Millets can be successfully cultivated in water stress conditions. Thus, in the states like Tamil Nadu, Madhya Pradesh, Orissa, Maharashtra and Gujarat among others there is a huge scope of increasing the production of millets by bringing fallow lands under cultivation. In recent times, states like Tamil Nadu already incentivising millet cultivation in identified waste/ fallow lands in the state.

3. Increasing the cropping intensity in dryland agriculture

Most of the farmers in dryland parts of the country go for single crop in a year due to unavailability of water to irrigate the crops. This significantly reduces the national cropping intensity which stands to be 145%. This calls for proper crop planning to utilise all three seasons of kharif, rabi and summerin the dryland conditions. Millets are the most viable solution in maintaining the all year cropping system in the dryland agriculture. Most of the millets are short duration in nature (generally 65-80 days) and can be successfully grown in the post-kharif fallows. Given the minimum requirements for water, small millets like kodo, little and barnyard millets can be successfully grown in the post-kharif fallows with the residual moisture content in

the drylands on country. This will significantly increase the cropping intensity in dryland agriculture and yield in throughout year income generation for the farmers. For instance; sorghum can be successfully grown throughout the year. Many parts of the country cultivate sorghum both in kharif and rabi seasons.

F. Policy options

Millets can also help in providing solution of food security issues of the future whereby the commonly consumed staple crops may not suffice to sustainably feed a projected large population of 10 billion by 2050. Millets can be answer for food and nutrition security and thereby meet the demands of planet and human health.

Green revolution induced supply– demand changes have placed the millet prices high and have limited their accessibility too. The best and proven way to bring down the prices and make them accessible food source is to increase the production backed by increasing demand. Hence the policy intervention is key for millets production and consumption to increase and thus to rebuild the nutritional security for the population.

1. Incentivizing cultivation

Incentivizing cultivation of millets may be an option till markets are established. Incentivizing millet cultivation (like that of Karnataka, Chhattisgarh, Odishaetc) may be taken up coupled with promotion of crop diversification from current practice of monocropping (like that of sugarcane and paddy) to enhance the area under millet cultivation.

2. Ease of access to farmers for primary processing

Primary processing machinery is required for value addition which is not available for farmers at this juncture. Even for home consumption, farmers need to go farther distances for processing of grains. Ready availability of primary processing machinery for each millet village clusters must be ensured. Proper training on machinery handling should be given. Support for branding and labelling for marketing in urban areaswould ensure that share of producers in the consumer rupee is higher. For this FPOs can be taken as a unit. More than 30 FPOs that are involved cultivation of millets have been established by the coordination of IIMR. Farmer Producers Organizations may be strengthened in such a way that pooling, cleaning, farm-gate processing, storage and supply to market will enable them to reap the economic benefits for their enhanced incomes, which will have a huge motivation for increasing the millets cultivation area. Strengthening FPOs to focus on entire value chain and to sustain as a group is more feasible. For farmgate processing FPOs may be provided with primary processing machinery. A package of Rs. 15 lakh for each FPO may be provided. Further, support for value addition in terms of secondary processing, if given, would further make cultivation and value addition of millets more lucrative.

3. Assured procurement of millet grains, fixing MSP for small millets and biofortified varieties

Assured procurement of sorghum, pearl millet and ragi grains have been lacking in the past, though higher MSPs are being fixed each year. In case of other small millets, even MSP is not being declared. Declaration of MSP with assured procurement would result in enhanced and

stable production area under millets. Local procurement at designated spots and use of the grains in PDS, Mid-Day meals, etc. would increase production and consumption of millets ensuring income security to farmers and nutritional security of the masses. Thus there is a need to push for government intervention in procurement of millets and their inclusion in public funded programmes. Government must also ensure that premium price is given for biofortified varieties.

Inclusion of millets in PDS, ICDS, MDM and other programmes of central and state governments is essential for ensuring the nutrition to women, children and common public, and procurement security for farmers. Considering the low shelf life, localized procurement and distribution can be efficient while supplying the excess grain to other locations.

The challenges, processes in value addition in preparing Ready-to-Eat Millets as healthy food

1. Absence of Gluten

Unlike the fine cereals, millets lack gluten (a protein formation as available in wheat) in them which is an essential factor for value addition. The current research efforts by IIMR led consortium have addressed the challenge by manipulating the starch instead of protein through hydrothermal treatment resulting in starch gelatinization. Through gelatinization, the diversification of value addition is possible to some extent but making some products like bread, buns, etc. with 100% millets is still a challenge. Intense research efforts on exploring the processing techniques and blending/ fortification with other ingredients are necessary for addressing this challenge and moving ahead.

2. Enhancing shelf life of value-added products

The current level of shelf life of millets is less compared to other major cereals. Bringing good taste and convenience with an increase of shelf life from less than a month to six months in some technologies, given a hope to commercialize millets. With integrated shelf-life management, the focused efforts to increase the shelf life to at least 8-10 months is vital in tapping the potential of export markets.

3. Primary Processing

In millets, the importance of machinery was demonstrated by becoming one of the reasons for diminishing consumption led by decades of our focus on food systems based on rice and wheat. Even after a decade of efforts, the primary processing machinery is still a challenge. The major millets-Sorghum, Pearl millet and Finger millet are the naked grains that don't have the outer coat and thus require no/minimal primary processing.

- But the minor millets such as Little, Kodo, Proso, Barnyard, etc., have the inedible outer coat called husk which needs to be removed in primary processing for making them suitable for human consumption. As the minor millets are small and of varying sizes, the efficiency of current machinery is very low with the recovery of 70 – 80% of grain and the remaining being the un-hulled and broken grains. This inefficiency is posing another difficulty in terms of separating un-hulled grains from the de-hulled grains.

- Coming to capacity, the current machinery is available in small capacities up to 2 tons/hour which needs to be scaled up for bulk processing by food manufacturers while the higher capacity machines are of high cost and unviable for micro, small and medium enterprises.
- Millets having varying size and physicochemical characteristics, they require different processing conditions such as the number of passes, speed, clearance, etc. which cannot be handled by existing machinery.
- The shelf life of processed grain is low compared to un-hulled grain, and thus some studies required for the optimization of polishing, milling, etc. for attaining the maximum shelf life.
- Currently, there are no standards on the degree of polishing of grain, as in the case of rice. Some studies for preparing the grades, standards and degree of polishing are essential for preserving the quality of the grain, nutrition, etc.
- Design of common aspiration system for the dust-free operation for cleaning and milling section
- Study on infestation control for improved grain storage with low-cost equipment
- Upscaling of secondary processing machinery and new product development: The current diversification of product technology is limited to only local tastes and preferences and thus, more technologies for continental and export market-specific recipes are necessary.
- Fortification: Like any commodities, millets also have limitations such as their amino acid profile has lysine as constraining quality protein factor, while pulses have low methionine. To complement these nutritional gaps, research on fortification with other ingredients such as pulses, milk, mushrooms, moringa/drumsticks, etc. is necessary.
- Diversification into Plant-based protein and other emerging research on New product development: The research efforts on exploring Plant-based protein as an alternative option for the vegetarian and vegan diet are still in the incipient stage and need acceleration.
- Grades and standards: Currently, small millets do not have the standards and grades required for procurement, processing, etc. to comply with the FSSAI norms of labelling.
- Packaging, labelling: The study of various packging techniques, material, etc. for establishing the packaging standards for various millet products are needed for the optimum shelf life suiting the requirements of domestic and international markets.

Required Market linkages:

1. **Backward linkages:** Formation of Millet based FPOs' which is on through DAC&FW National submission on millets launched in 2018, 100 FPO's are to established in 3 years through SFAC in millet growing states. With proper supply chain in place these FPO's would serve as growth engines for forward linkages with markets. ICAR-IIMR is given an opportunity to model few millet based FPO's with not only storage infrastructure but also postharvest processing support, but also market development support to strengthen forward linkages.Development of infrastructure for on-farm storage of grains is vital in maintaining the quality of grains, especially from moulding in the monsoon season for increasing the marketability of the products, the realization of higher prices and build linkages with markets.
2. **A higher share of the producer in consumer rupees:**Enabling the farmer with adequate support for farm gate value addition is required for ensuring the quality and consistency for

supplying to start-ups and processors. This intervention will help them realize more income as a share of the consumer rupee.

3. **Linking start-ups with Captive Government Markets:**Building the linkages between the captive markets such as publicly funded programs and the start-ups/processors will result in a solid supply-demand chain. Further, the start-ups to be linked with the backward linkages such as FPOs or SHGs for creating solid Supply chain linkages.
4. **Linkages between start-ups and Big private players:** Building an ecosystem where start-ups can process the products for big private FMCG player on contract manufacturing will result in inefficient use of capacity while the big players can concentrate on penetrating the nutrient-rich products into domestic and export markets.
5. **Creation of Export specific Clusters:**Identification and grouping the millet growers, and linking with the export traders/processors will establish the sustainable supply chain for exports.
6. **Creation of Export Promotion Forum:** Building an ecosystem of seamless linkages between producers, processors and export traders will aid in strengthening the value chain for export markets. This forum will also organize sensitization and capacity building programs for promoting the export of millets.
7. **Market Intelligence:** Analyze the export competitiveness of millets and price volatility of domestic and international markets. Market Intelligence with information on standards of international markets, emerging segments, regulations and trade policies in the public domain and consumer preferences.
8. **Developing segmented markets and upscaling them:**Analyzing and segmenting the markets for building the product portfolio along with appropriate marketing and branding strategies is necessary to position the millets and scale up globally.
9. **Marketing, branding, labelling and packaging:** A package of strategies for Branding, Positioning, USP and Marketing in various consumer segments, countries or regions is needed to position them efficiently.
10. Other market linkages include RTC/RTE (ready to eat or ready to cook) based Niche markets for catering convenient healthy foods to meet urban consumer requirements; rebranding of traditional Rural markets for local consumption and wide community engagement, beyond CBE (Community based events) and VHSND (Village Health Sanitation and Nutrition Days) involving KVK's, forest protection committees, School management committees in rural areas and engaging health-conscious millennials from Urban IT-based congregations.

G. Overall recommendations

Seed systems

- Developing a robust seed system for states to increase the area and production of millets (including small millets) may be taken up on priority basis

- There is a need to improve the varietal replacement ratio with current 35 % of the varieties to higher levels with additional focus on including the small millets in seed value chain.
- Millets seed hubs need to be provided operational fundingin the form of revolving fund as given to pulses and oilseeds (This revolving fund support is not provided to Millet Seed hubs and should be given if Seed hubs have to perform, sustain and make available quality seeds on long term basis to usher is millet revolution) to hasten the dissemination of latest varieties into seed chain to augment productivity. The seed hubs need to be connected with state and national seed corporations to make requisite quantities of seeds of improved varieties to all the states.
- National Seed Corporation (NSC) to devise a plan along with ICAR-IIMR to utilize the farm facilities for seed production (including multiplication) and plan for distribution of minikits to hasten production and multiplication of certified and foundation seeds.
- Provision of production subsidies for private seed companies for producing millet seeds to ensure better penetration and spread of quality seed in dryland areas, which can increase production by 20%
- Private sector may be encouraged to provide R&D support to produce and multiply large quantity of seeds through their involvement in collection of germ plasms and breeders' seed production.

Area Expansion

- Enhancement of production of millets may be taken up by increasing the area under millets and improving the productivity of millets by using HYVs, introduction of millets in better endowed areas, fallow and wastelands
- There is a need to identify the regions with reduced area under millets and create better profitability in millet cultivation through intensified breeding programs by creating HYVs like that of competing crops
- Expanding the area under millets may be taken up through promotion of organic cultivation and bio-fortification of millets.

Crop improvement

- Identification of product specific cultivars for different products of the industry (for all millets) may be taken up to push the industry participation in demand creation which further contributes to enhanced area and production.
- Region-specific cultivar development may be taken up for greater adaptation and acceptability of improved varieties

Policy support for incentivizing millet cultivation

- Incentivizing millet cultivation (like that of Karnataka, Chhattisgarh, Odishaetc) may be taken up coupled with promotion of crop diversification from current practice of monocropping (like that of sugarcane and paddy) to enhance the area under millet cultivation. The support of Rs. 10000/- per hectare be given for incentivizing cultivation on all India basis so that we can mainstream millets in Punjab, UP and Eastern India where yields 4 times more than national average. This will help in augmenting higher

production for export while we achieve crop diversification with millets to diversify food plate of all with millets.

Policy support for processing of millets

- There is a need to develop a strategy to rope in FPOs to promote farm-gate processing and value addition of millets to strengthen the supply chain and value chain of millets. A financial support of 15 lakhs each for primary processing of Millet based FPOs should be given without fail, this will help in removing bottleneck of primary processing and help in creating direct marketing linkages by FPOs.
- There is a need to push for government intervention in procurement of millets and their inclusion in public funded programs alongside involving private sector for hybrid sector for efficient seed production and multiplication.
- Cluster based approach may be adopted to take up processing and value addition of millets by FPOs in different millet clusters with primary, secondary, and tertiary processing of millets including their participation in procurement of millets for PDS in government schemes.
- There is a need to build a sustainable model of millets (including all the aspects of supply and value chain of millets) for branding and positioning of millets in local and global markets
- There is a need to address the gaps in post-harvest and storage of millets and promote them for consumption at local and global levels through increasing area under millets (including small millets).

Policy support for MSP and assured procurement of millets

- Declaration of MSP for small millets and assured procurement of all millets would result in enhanced and stabilize production area under millets.
- Inclusion of millets in PDS, ICDS, MDM and other programmes of central and state governments is essential for ensuring the nutrition to women, children and common public, and ensuring income security to farmers
- Local procurement at designated spots and use of the grains in PDS, Mid-Day meals, etc. would increase production and consumption of millets and nutritional security of the masses.
- Government must also ensure that premium price is given for biofortified varieties.
- Localized procurement by hilly tribes in hilly and tribal tracts may be encouraged to promote local consumption and improve the marketability of millets.

Preparedness for IYM 2023

- Address the gap in production and consumption of millets globally by providing proper market connect and catch the advantage of IYoM 2023 ahead of other countries.
- Nutrition profiling of millet cultivars (more than 154 in Nos) may be taken up to show their potential alongside capturing the global market for gluten free and vegan foods in the form of plant-based protein.

Strategic Action Plans for Mainstreaming Millets

Strategic Action Plan-I: Enhancement of Production & Productivity

- Incentivizing cultivation Rs. 10000 per ha – limited to three hectares per farmer for next 5 years to hand hold farmers to meet most needed domestic demand and to build exportable surplus
- Implementation of National Food Security Mission Programme in the all millets growing areas and Non Traditional states to augment higher production.
- Production of Breeder, foundation and certified seed of Millets improved high yielding varieties through seed hubs & SAUs, seed agencies and private sector
- Production incentivization for seed enterprises to have seamless access of quality seeds and to achieve seed and varietal replacement
- Millet FPOs need be supported by providing primary deshelling and secondary processing machinery for better quality produce. This is main bottle neck as there are no millet mills. Support if 30 lakhs per Millet FPO will be the change maker for millets

Strategic Action Plan -II: Value addition, Processing & Recipe

- Product development –RTE/RTC/Conveneience foods and Express foods
- Research on Degree of Polishing,
- Evaluation on the effect of various processing techniques on nutritional value,
- Nutritional epidemiological information of processed foods,
- Research on Nutritional rich fractions and nutraceuticals with by-products,
- Research on improving shelf-life of value-added products,
- Diversification into plant-based protein, lab-cultured meat and other emerging research,
- Packaging
- Development & Documentation- Both National and International recipes.

Strategic Action Plan -III: Entrepreneurship/ Startup/ Collective development

- Development of FPOs
- License of Entrepreneurs, Processors, Startups and Tourism.
- License of service provider for supply of millet products in the country.
- Inclusion of millets under ODOFP in all millet producing districts.
- Awareness campaign for adoption of millet products.

Strategic Action Plan -IV: Nutritional & Health benefits

- Profiling of Millet Cultivars for Nutritional Parameters & bioactive compounds
- Clinical trials for bioavailability studies & functional properties of the millets
- Study on efficacy of Therapeutic properties of nutrients.
- Study of shelf life of the millets flour and ready to use products of millets.

Strategic Action Plan-V: International Outreach

- South-South Triangular Cooperation (SSTC), where India and African countries signed MoUs, for

- Developing of Seed System.
- Organic cultivation and Trading of Millets.
- Establishing and/or Replicating of Value Chains.
- Entrepreneurship Development.

Strategic Action Plan-VI: Learnings from the models of Karnataka, Odisha and Maharashtra

As per the Study by DAC&FW and FAO in Karnataka, Maharashtra &Odisha states, the following recommendations are proposed for mainstreaming millets at national level.

- Establish a national millet-focal point to oversee all aspects of 'nutricereals'
- Organize a public campaign to promote awareness of the benefits of millets amongst consumers, both urban and rural.
- Build synergy between MoA&FW and other ministries and departments running nutritional programmes or activities related to climate resilient food and farm systems. Promote consumption by including millets in ICDS, MDMS and PDS, where they have not yet been integrated.
- Develop strategies to strengthen millet ecosystems, based on learnings from this study. Facilitate processing by establishing hubs, necessary infrastructure in millet corridors and set standards, supported by a national study on the bioavailability of nutrition from millets.
- Strengthen R&D support for specific needs. Strengthen R&D on various technical needs, particularly processing technologies and diversify into alternative uses through stronger linkages with research institutions and relevant authorities such as CFTRI, IIMR, IIPFT, NIFTEM and FSSAI
- Ensure assured returns to farmers for producing and processing 'nutri-cereals' with incentives and disincentives for the same. Synergize existing programmes, such as those on human nutrition and climate preparedness; dovetail the efforts to improve farm incomes with the DFI strategy, by primary and secondary processing and B2B sale.
- Develop standards for all millets and their products, notified under appropriate regulations, such as those on food nutrition labeling and display.
- Develop millet corridors: Millet corridors should have several processing hubs that will provide backward linkages to producers for procurement (as well as supply of millet rice for local consumption) and also value addition for marketing to consumers.
- Business Incubation: Entrepreneurs play a crucial role in risk taking and market development. Business incubation facilities should be available in each Millet Corridor addressing all aspects of business development - technical, financial, marketing and managerial, human resources, etc.

Summary of Recommendations

A. Production and Procurement

- **Expansion of millets cultivation**across the country by including non-traditional areas by leveraging ICAR network of millets coordinating centres and ICRISAT. This would

happen when farmers get higher share in the consumer rupee through value addition process.

- **Productivity Enhancement** through Implementation of Agro-climatic zone wise planning, Cluster approach, and wide extension of improved technologies such as seed, integrated nutrient management (INM), integrated pest management (IPM), input use efficiency and resource conservation technologies to the farmers and extension functionaries.
- **Development of Biofortified Varieties** which are significantlyrich in iron, calcium, zinc, etc. for serving the nutrition sensitive segments such as infant foods, diabetic friendly foods, ICDS recipes, etc.
- **Identification of Cultivars and Strengthening seed chain**: Profiling of end-use specific cultivars is a major step towards achieving Demand-driven production. Processing and delivery mechanisms for quality seed supply.
- **Promotion of Millet FPOs and Farm-gate Processing:** Farmer Producers Organizations may be strengthened in such a way that pooling, cleaning, farm-gate processing, storage and supply to market will enable them to reap the economic benefits for their enhanced incomes, which will have a huge motivation for increasing the millets cultivation area.
- **Declaring the MSP and Procurement** for all millets and procurement of the grain by state governments, FCI, etc. will provide the income security for millet farmers.
- **Inclusion of millets in PDS, ICDS, MDM, etc.** programs by central and state governments is essential for ensuring the nutrition to women, children and common public, and procurement security for farmers. Considering the low shelf life, localized procurement and distribution can be efficient while supplying the excess grain to other locations.

I. Strategies for taking forward R&D efforts on Critical gaps

- R&D on advanced primary processing machinery, degree of polishing standards, enhancing shelf-life from current levels, studying secondary processing techniques for their impact on nutrition, diversification into both regional and export food trends, grades and standards, packaging standards for various products and studies on nutritional evaluation, bioavailability, efficacy for health benefits, etc. are essential for scaling up the value chain.
- **Training, Capacity building, Incubation and funding**support to millet startups for entrepreneurship development and linking them with government/captive markets, niche markets, and export markets, for increasing the number of food processors and exports within the country. Building such capacities by establishing new millet specific incubation centres will accelerate the whole efforts.

- **Encouraging the big private food processors**for including the millets into their product portfolio by bringing a policy for incentivizing the setting up of processing units and/or processing activities.
- **Strengthening the Small and Medium Enterprises**would play a pivotal role in pushing the millet products in local markets, and supply to government programs.

II. Positioning and exporting to Global markets

- **Strategically aligning the Indian millets with emerging food trends**of various potential export markets such as Japan, Indonesia, Germany, Belgium, The Netherlands, Italy, the UK, Poland, China and Rep. of Korea which draw more than 64% of total millet imports, while balancing the India's current exports to traditional export countries in Asia and Africa.
- **Bringing the millet specific export policies**such as allocating the separate HS codes for all millet products, including them in RODTEP scheme, PLI scheme and other schemes such that the wide range of millets products are encouraged.
- **Building the Export specific production cluster and promotion forums** would enhance the exports from India.
- **Other market related activities** such as building market intelligence on export countries, trends, prices, etc. for enabling the informed decisions by exporters.

III. Popularization and Strategic Awareness Creation

- **Leveraging the International Year Millets** for global level awareness creation and popularization by organizing various kinds of events till 2023 and in 2023 is very essential, as India is the largest producer of millets and also the prime beneficiary of millets promotion. It's important to get ready with calendar activities for organizing as a run up for the International Year of Millets, 2023.
- **Hosting the international and national conferences,** food festivals, trade fairs, etc., for creating dialogue on various policy, scientific, promotional and consumption aspects while acting as a platform for developing linkages would expand the millets reach to various communities.
- **Leveraging on the global platforms such as South-South Triangular Cooperation (SSTC)** for awareness creation, knowledge sharing, capacity building, technological support, incubation, etc. for replicating the successful models of India towards strengthening the global value chain on millets.
- **Building USP**around individual millets and also positioning 2–3 selected millets as champion millets by tying with a unique proposition such as milk for calcium, egg for protein, etc. for effective marketing in both domestic and export markets.
- **Taking millets closer to people** through various awareness creation programs such as advertising in print media, electronic media (TV Channels, Radio), social media, Indian

Railway, Anganwadi, etc., should be exercised by the Government, as in case of eggs and milk promotion.

- **Convergence of various departments**such as NITI Aayog, APEDA, MHRD, MOFPI, MSME, etc., and other public institutions, premier institutions, private sector, NGO's, farmer groups, chefs, dieticians, doctors, nutritionists, startups, etc., would open the possibilities for tremendous awareness creation.

IV. Constitution of Millet Advisory committee to advise government to implement the Vision and Plan of Action on Millets encompassing following terms of Reference

1 Strategies to boost domestic production and consumption of Millets, including steps to build exportable surplus to expand India's leadership position in Millets

2 Action plan for Modernization of the Millet Processing Machinery and strengthening farm-gate processing and value addition to devise strategies that enable linking millet farmer to Market

3 Ways and means to strengthen and promote existing and novel value and supply chains, connecting FPOs with processing mills, facilitating contract farming, improving storage and transport logistics, promoting warehousing, as also digitization of the supply chains

4 Suggest Strategies to promote export of value-added Millet products and interventions for developing end products through sharing of expertise among the research institutions working on Millet Research, Machinery, food processing, value addition, incubation, capacity building to enlarge land scape of market for these neglected commodities.

5 The Committee should also consider advising the department and the government on:

a. Incentivizing Millet cultivation, Farm-gate processing and Farmer producer organizations

- Pan-India Incentivisation needed to support millet area expansion in traditional and Non-Traditional areas to enhance production and productivity
- Primary processing machinery required for value addition
- Training requirement on machinery handling
- Branding and Labeling for marketing
- Strengthening FPOs to focus on entire value chain and to sustain as a group
- Support for value addition in terms of secondary processing

b. Strategies & policies for Enhancing Production and Productivity, including R&D gaps in production and productivity

- Mapping Millet expansion in Non-traditional Areas to augment higher production
- Reviving Endangered Millets of Himalayan, Hilly, Tribal belts
- Strengthen the scientific and technological capacity to move towards more sustainable consumption and production meeting the SDG goals of Responsible Consumption & Production
- Organic miliets- potential areas for earmarking
- Profiling of Millet cultivars based on nutritional parameters and Identification of End Product-specific Genotypes for value addition

c. Addressing R&D gaps in Millet Nutritional profile, bioavailability and Health benefits and mainstreaming millets in public funded programs.

- Clinical trials for Evaluation of Bioavailability of nutrients and validating health benefits of Millets. Supplementation trials for Functional Properties
- Studies on the efficacy of Therapeutic properties of nutrients
- Establishment of Standards and Guidelines to optimize milling based on the nutritional value of Small millets by degree of polishing (DoP)
- Nutritional Epidemiological information of processed foods
- The measure of physiologically active bio compounds in altered foods compared to raw millets
- Mainstreaming millets in Public Funded Programs-Captive/Mass Government Markets

d. Addressing R&D gaps in enhancing shelf life of Millets (grains/ flour/value added products)

- Increasing the shelf life up to 6-9 months for RTE/RTC/RTS milletbased products by using thermal (sterilization, pasteurization, parboiling, etc.) and non-thermal (irradiation, cold plasma, Pulse Electric Field, Microwave heating, IR, UV sterilization, etc.)
- Establishment of the storage protocols for improving the keeping quality of the millets and its value-added products.
- Identilication of the suitable packaging material for each millet product to enhance the shelf life
- Developing and documenting novel millet product development, value addition and recipes including linkages of markets and millets for promotion as healthy food.
- Scaling up of technologies would increase price affordability and accessibility
- Research studies to strengthen the database on health benefits

e. Formation of Millet Promotion Council

- Form a collective body to converge different stakeholders in millets by bringing in industry, startups, entrepreneurs, Govt agencies, academia, research, and academic associations, NGo's., state Govts, etc
- Creation of a Millet Export Promotion Forum with all concerned stakeholders for integrated export promotion nationally
- Identifying Export market trends and potential for various millet value added products
- Framing the USPs for various product segments of domestic and international markets

ECOLOGICAL FARMING OF MILLETS IN INDIA

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Millets (sorghum, pearl millet, finger millet and small millets) are rechristened as nutri-cereals in 2018 by Government of India by adding two pseudo millets (buck wheat and grain amaranth) are cultivated on 12.181 m ha during 2021.Predominantly rain fednature of millet cultivationon poorly fertile soils up on receiving low & imbalanced fertilizer inputs with little or no attention towards pest management have low productivity (1208 kg/ha). The advent of green revolution has relegated millet crops culture and consumption to stressed agro-ecologies.However, the increasing spread of life style diseases (blood pressure, diabetes, celiacdiseases etc.) among consumers have paved way for organic / natural foods consumption. Millets nutritional profilebeing different from that of predominant staples (rice, wheat, maize etc.) are seen as potent alternatives. Inherently millets production systems reliance on external inputsis low thatcanbeturnedinto no external input system without compromising on their productivity. A conversion period of two years is set to become a farm from inorganic to organic. The premium price commanded by organic millet produce could boost the economic wellbeing of the farmers at current productivity.In this context, millets are ideal candidates for organic production and thus in future, organic production will be one of the potential growth engines. As per APEDA, cereals and millets together account for 9.26% (3.468 m t) of total certified organic production of India during 2020-21, and the share of millets out of this is very meagre. The organic millet cultivation practices developed in India are briefed below.

Organic millet cultivars and regions

Small millets (except finger millet) cultivated in isolated pockets in hilly areas by tribal farmers without external inputs can be directly marketed as organic produce without the conversion period. Pearl millet cultivated in A1 zone (with <400 mm rain fall), *rabi* sorghum cultivated on residual soil moisture in vertisols and 'Guli' finger millet can be converted in to organic millet production with or without conversion period. Millet crops that are grown organically in different states are given in Table1.

Table 1. State wise millet crops grown under organic farming in India

State	Millet
Arunachal Pradesh	Sorghum
Karnataka	Sorghum, Finger millet
Sikkim	Finger millet, buck wheat
Uttarakhand, Maharashtra	Sorghum, Buckwheat, grain amaranth
Odisha, Andhra Pradesh, Chhattisgarh, Madhya Pradesh	Finger millet, small millets
Rajasthan	Pearl millet

Cultivars

Regarding varieties, there are no transgenics cultivars in millets however, hybrids are available in pearl millet and sorghum. As there is no restriction on use of hybrids in organic farming, all available millet cultivars (hybrid / variety) can be used in organic farming. However, the use of hybrids in pearl millet and sorghum requires higher doses of nutrition than the varieties. Selection of biotic stress tolerant cultivars becomes a key strategy for organic pest and disease management.

Crop nutrition

In organic farming, soil organic carbon (SOC) forms the fulcrum of soil fertility, however, its build up is difficult (but achievable in long run) in tropical countries like India due to high temperatures and low rainfall.As livestock are integral part of millet farming, animalmanures (FYM) could form the main source of nutrients while crop residues can be recycled directly or after compost making as source of nutrients.Further, green manures and green leaf manuresalso could also act as source of manures.Release pattern of nutrients from manures over time needs to be understood that could serve as supply indicator tocrop (Table 2). Oil seed cakes (edible and non-edible) application to soil and foliar spray of sea weed extracts were found to aid organic nutrition of millets. Bio-fertilizers (N, P, K and Zn) especially in their liquid form could aid in fixation (N) and mobilization of nutrients from soil reserves for crop uptake. Intercropping of millets with legumes is most extensively followed in the country as a risk coping mechanism and theirNitrogen sparing and transfer mechanisms to component cereal crops comes handy in organic farming. In cropping system too, millets cropafter legumes derive N transfer benefits. As manuring is often done on N basis, the insufficiencies of phosphorous (common) and potassium (rare) needs to be addressed and in this direction, rock phosphate and potassium sulphate, the permitted mineral fertilizers for organic farming comes handy. Natural farming based on use of organic liquid formulations (Jeevamrutha, Panchakavya, Beejamruth) prepared from animal products (milk, curd and ghee) is advocated. These formulations containing macro, micro nutrients, vitamins, essential amino acids, growth promoters (Indole acetic acid, Gibberellic acid) and beneficial microorganisms' aids in plant nutrition and plant protection too.

Table 2. Half-life period of nutrients present and the manures

Organic amendment	Half-life period (days) and nutrient									
	P	**K**	**Ca**	**Mg**	**S**	**Zn**	**Cu**	**Fe**	**Mn**	**B**
FYM	167	72	350	373	303	134	287	214	122	82
Mushroom compost	190	90	209	364	293	123	367	162	113	63
Poultry manure	187	78	273	120	233	148	118	119	122	107
Vermicompost	195	109	189	320	776	138	288	198	122	107
Biogas slurry	184	70	131	222	192	99	636	126	111	90
Leucaenabiochar	234	68	590	289	320	92	298	120	104	106

Weed management

Studies have indicated that both diversity and biomass of weeds increase under organic production systems and more so in initial years of organic farming under influence of adoption of non-chemical weed management options. Thus non-chemical weed management becomes a great challenge thatoften becomes the reason for discontinuance of organic farming by farmers. Use of properly decomposed manures in organic production aids in lessening weed seeds addition to the soil.Proper primary tillage and interculturaloperations aid in effective weed management. Rapidly declining draught animals (24.43% decline between 2012-2019 as per Livestock Census of India) not only depreciates manure production but their role in tillage operations and weed management. This calls for greater use of mechanical power for tillage and weeding. Stale seed bed and soil solarisation techniques come handy in weed management in organic millets. Transplanting of crops (pearl millet and finger millet) in lieu of direct seeding was also found to give edge to crops over weeds. Hand weeding will be the other option to manage the weeds. However, decline in manual work force for agriculture (17.05% decline in manual work force employed in agriculture between 2000-2019 as per ILOSTAT data base of World Bank) and their ever escalating costs makes the economic weed management a challenge. Conservation agriculture will also come handy in organic weed management.

Integrated pest & disease management

Integrated pest and disease management solution though selection of tolerant cultivars, clean culture (removal of affected parts, burning), seed treatment and use of botanicals etc. have been perfected to contain losses below economic threshold levels.

Way forward

All production practices when integrated as a package and adopted could make the organic millet production a reality.Even the low production of organic farms in initial and in subsequent years too as compared to inorganic farming gets more than compensated by the high price (50-100% more) commanded by the organic producethat could boost the millet grower'sincome and can maketheir livelihoods more sustainable. Export of organic millets like processed finger millet and barnyard millet from Uttarakhand to Denmark through initiatives of APEDA, in collaboration with Uttarakhand Agriculture Produce Marketing Board (UKAPMB) & Just Organik, an exporteris a step towards boosting opportunities in organic millets cultivation.Linking of producers with national consumers directly (excluding middle man) and branding of produce will make the organic millet cultivation more profitable. In this direction, Farmers Producers organisations (FPOs) will come handy. Huge labour requirements of organic farmsresult in creation of huge employment opportunities to farm labour locally that could reduce the migration to urban areas.

INTRODUCTION OF INDIGENOUS AND EFFECTIVE MICROBES IN ORGANIC AND NATURAL FARMING SYSTEMS OF MILLET CROPS

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Millets are generally a group of small, grained cereals needs less input for cultivation such as fertilizers and pesticides. It can grow under poor or less fertile soil and rain feed or low rainfall area. Generally, the most of millets are Indian origin and called as nutri-cereals due to its rich nutritive values like crude fibre, mineral matters, iron, calcium, potassium, magnesium, zinc, phosphorus, etc and trace amount of vitamins and folic acids which required in daily diet of human for normal functioning of body. Due to low glycemic index (GI), its boon to diabetic patients and reduces the risk of diabetes mellitus. The millets are classified based on the size of the grain namely, major and small millets. The major millets include sorghum (Sorghum bicolour L.) and pearl millet (Pennisetumglaucum(L.) R. Br.)) and small millets include finger millet (Eleusinecoracana(L.)Gaertn.), foxtail millet (SeteriaitalicL. P. Beaurv), little millet (Panicumsumatrense), kodo millet (PaspalumscrobiculatumL.), prosomillet (Panicummiliaceum(L.)), barnyard millet (Echinocloafrumentacea) and brown top millet (Brachiariaramosa (L.)).There are traditional millet farming in India include, "Baranaja" farming practices from Himalayan region include sowing of 12 different crop at same time in same place. The "SaatDhan" system followed in Rajasthan sowing variety of millets together. The "PannenduPantalu" practices from southern India include cultivation of millets with oilseeds and pulses. In ancient years, millets are the first domesticated by human beings in Asia and Africa continents and spreads around world as a source food. In India, millets are first cultivated crop and considered as a staple cereals in the "Hoe Age" before the "Plow Age". The evidence found in Harappa Civilization (2500-2200 BC) at Shikarpur (Kutch- Gujrat) and later in Punjab (1900-1400 BC). The millet farming spreads around different agro-climatic and soil conditions of Indian states like Karnataka, Tamil Nadu, Andhra Pradesh, Maharastra, Madhya Pradesh, Odisha, Jarkhand, Uttarakhand and Chattisgarh. The farming practices of millets are very eco-friendly, so its spreads from hilly region to drylands agricultural system.

In recent decades, components of sustainable agriculture are an important topic due to its impact on soil and human health and became debatable among the famers, scientists, biologists, conservationists, ecologists and policy makers. There are different practices which helpto keep good environmental health, economic profitability, and social equity in eco-friendly agriculture programme.

Organic farming is an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity.The important principles of organic farming viz., health, care, ecology and fairness needs to be addressed among the practitioners. There are different components in organic farming like crop rotation, utilization of crop residues as manure, application of organic manure like FYM, green manure and compost, application of biopesticides, biofertilizers and vermicompost which will improve the fertility of soil. Natural farming (NF) defined as a chemical-free alias traditional farming method

considered as agroecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity. The components of natural farmingBeejamrit, Jeevamrit, Whapasa, plant protection practices Neemastra, Brahmastra, Agniastra, Dashapani Ark or Kashaya. There are different ingredients used in the components of natural farming practices viz., cow dung, cow urine, lime, jaggery, pulses' flour, botanicals extracts like, neem leaves, karanj leaves, custard apple leaves, datura leaves, mango leaves, tobacco powder, green chilli, garlic paste, turmeric powder, ginger paste, asafoetida, milk, curd and etc. There are major initiatives taken by NITI Aayog, Government of India (GoI) through the concept of Zero Budget Natural Farming (ZBNF) in Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Uttarakhand, Kerala and Karnataka and implemented ZBNF- the farmers in these states are treating seeds with Agniastra, Brahmastra and Neemastra.Indigenous microorganisms (IMs) are a group of innate microbial consortium that inhabits the soil and the surfaces of all living things inside, and outside which have the potentiality in biodegradation, bioleaching, bio composting, nitrogen fixation, improving soil fertility and as well in the production of plant growth hormones. IMOs-based technology was developed and introduced by Dr. Chou Hankyu in 1960s.Natural farming with IMO Technology is a distinctive approach in organic farming and it has been practiced in more than 30 countries in their home gardens and on a commercial scale.Effective microorganisms (EMs)are cultured mixture of beneficial microorganisms. The main difference that divides these two ideas is that IMOs are naturally made, while EMs are laboratory made, but these are very much the same with one another in all aspects. There many successful effective microbes namely, Trichodermaspp, arbuscularmycorrhizal fungi (AMF), Actinobacteria, Pseudomonasspp., and Bacillusspp. These species are identified as a dominant microbial community as such from soil which inhibit the growth of soil borne pathogens and induce resistance in host against pests. The applications of more microbial load of these Ems are very useful in the biological management practices of plane pest management and the impact of the root microbiome on plant health is evidenced most clearly in disease-suppressive soils.

The key challenge in future work can be protection and conservation of biodiversity in different ecosystem. The application of microbial inoculants has improved the soil ecosystems which are helpful in plant growth and pest management. Due to inconsistent efficacy in different agroclimatic conditions, there is an urge to explore and adopt large scale of microbial inoculants in natural farming practices.Soil conditions and losses due to plant diseases directly affect the yield and nutritive quality of the millets,major threats to its cultivation in poor and degraded soil. Though crop production and protection can be made by the application of chemical fertilizers and pesticides, but their application in long run may result in poor soil fertility, disrupted soil habitats, and may increase environmental and groundwater pollution. The utilization of chemicals and fertilizers is one of the key reasons causing soil contamination by enhancing its salinity, making it inconvenient for crop bearing and adversely influencing the soil microorganisms. Salinity negatively influences growth and net photosynthetic activity and a reduction in photosynthesis may also be due to a decrease in chlorophyll content.The millets are mainly suffering from foliar and grain pathogens. There are some major diseases of millets namely, blast, rust, smut, grain mould, downy mildew, brown spot, Ergot/sugary disease, leaf blight, bacterial leaf streak, bacterial leaf stripe, bacterial leaf spot and some viral diseases like Indian peanut clump virus, maize dwarf mosaic Virus, maize streak virus also affects yield and

grain quality of millets.In millets, there are some insect pests which affect the stem, root and leaf are shoot-fly, stem-borer, and white grubs.

Biological control strategies are based on microbial interactions. The microorganism's behaviour is governed by various mechanisms namely competition for nutrient and space, antibiotic production, growth of microorganism over the others (hyperparasitism and mycoparasitism), cell wall degradation, secondary metabolites and different signalling pathways of the host and microbes and their interaction. Different microbial consortia can also be used for better control of plant diseases. Strains of *Trichoderma* species against a wide range of challenging pathogens, their mechanism of action, survivability and rhizospheric competence with the changing climate, compatibility with the various components of integrated pest management, quality formulations and field success are the major issues which need to be further explored intensively (Sharma et al, 2014). Species of the multifaceted microbes viz., Trichoderma, Aspergillus, Penicillium, Mycorrhiza, Bacillus, Pseudomonas etc. registered in various formulations (granular/liquid) and marketed in various trade names, are such examples which may be included in any category (Sharma 2023). A wide range of *Trichoderma*species is not only effective against plant pathogens, but also against insect pests and therefore, it can become a good microbial solution for the upcoming natural and organic farming systems. Some effective strains of Trichoderma and Pseudomonas are useful for foot rot and sheath rot in small millets. Seed treatment with talc formulation of *Pseudomonas chlororaphis* SRB127 reduces charcoal rot incidence and increase seed weight (Das et al, 2016) .

Millet cropping systems also havevaried degrees of dependence on mycorrhizal associations, as influenced by the availability of nutrients in the soil in which they naturally occur. Mycorrhizal dependency was defined by Gerdemann (1975) as the degree to which a plant is dependent on the mycorrhizal colonization to produce its maximum growth or yield at a given level of soil fertility. There are studies on mycorrhizal fungi which illustrate the reduction in pathogens colonization, drought resistance and maintaining crop yields. In polyhouse trials Channabasava and Lakshman (2012) reported increase in growth and nutrient uptake in *Paspalumscrobiculatum* L. (Kodo Millet) using single and multiple AM fungal inoculaand they further assessed on the effect of mycorrhizae as a biofertilizers on millets with special reference to growth responses and phosphorous uptake, as AM can improve plant growth and development under nutrient deficient conditions. They also reported significant increase in millets biomass and altered root morphological structure in *Paspalumscrobiculatum* L. (Kodo millet), *Panicummiliaceum* L.(Proso millet), *Panicummiliare*Lamk. (Little millet), and *Setariaitalica* (L.)Beauv.(Foxtail millet). Presently with the upcoming organic and natural farming research are being conducted on the microbial solutions both for crop growth and protection. The change in attitude towards the non-chemical food has laid a foundation of microbial application in the agriculture. We need to be very specific in research and practical field application so that in a sudden upsurge of interest in millets their good agricultural practices available for the quality production and protecting the nutricereals.Theconsortial research on microbes is further giving us high hopes in managing the crops by introducing the effective microbial strains .

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CONVENTIONAL AND NATURAL FARMING APPROACHES FOR MILLETS

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The small seeded cereal crops termed as "Millets" are utilized for food and fodder purposes. They are considered to be the earliest domesticated food crops in Asia and Africa. Millets have been categorized in two groups, major millets i.e., sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetumglaucum* L.) and minor or small millets comprising finger millet (*Eleusinecoracana*L. Gaertn.), barnyard millet (*Echinochloafrumentacea*L.), little millet (*Panicumsumatrense* Roth ex. Roem. and Schult.), foxtail millet (*Setariaitalica* L.), kodo millet (*Paslpalumscrobiculatum*L.), proso millet (*Panicummiliaceum* L.) and brown-top millet (*Panicum ramose* L.). Buck-wheat (*Fagopyrumesculentum*) and Amaranthus (*Amaranthusviridis*) are categorized as pseudo millets.

Millets are mainly cultivated in Africa and Asian regions since ancient times. In India, during the past 50-60 years their cultivation and consumption reduced due to availability of high yielding varieties of rice and wheat and changes in food habit. However, in recent years, owing to their high nutritional values, low glycemic index, awareness to millets as nutri-cereals has increased and they are in high demand again. Millets are climate-resilient crops highly tolerant to drought stress and high temperature, and need less inputs. Therefore, under the changing climate scenario, these crops are more suited to arid and semi-arid regions of the country.

India is the leading millet producing country with a share of around 80% of Asia's and 20% of the global production. Millets in India were traditionally consumed, and grown as mixed and intercropping on marginal lands with low or no inputs resulting in low yield. However, with the development and release of hybrids and improved varieties especially in sorghum, pearl millets and finger millet, with improved production technologies, the productivity of these major millets has improved a lot, resulting increase in total production in spite of significant reduction in area in the last 4-5 decades Although, some of the small/minor millets like barnyard millet and proso millet have high yield potential, the productivity is still quite low, which needs to be increased through development and adoption of better genotypes and improved management practices. The millets are being promoted as nutri-cereals and as future crops. The Government of India realized the importance of millets in building nutritional security in the country and made several efforts such as gazetting millets as Nutri-Cereals, the celebration of the National Year of Millets in 2018, and several small-scale policies on milletsto promote millet cultivation and utilization through creating awareness, production, processing and value addition. On the initiatives of Govt. of India, the United Nation has declared the year 2023 as "International Year of Millets" to promote its cultivation and consumption.

Table: Area, production and yield of millets (2019-20)

Crop	Area (mha)	Production (mt)	Yield (kg/ha)
Pearl millet	7.54	10.36	1374
Sorghum	4.82	4.77	989
Finger millet	1.00	1.76	1747
Minor millet	0.46	0.56	809
Total	13.82	17.45	

(A) Improved varieties of millets

S. No.	Crop	Hybrid/Variety
1.	Sorghum	CSH-41, CSH-25, CSH-18, CSH-16, CSH-27
2.	Pearl millet	MP-535, MP-7872, KBH-108, GHB-905, ICMV-221
3.	Finger millet	VL-149, GPU-45, GPU-67, GPU-28
4.	Kodo millet	JK-137, KJ-48, JK-65, JK-439, DPS-9-1
5.	Barnyard millet	VL-29, VL-207, VL-172
6.	Little millet	JK-4, JK-8, JK-36
7.	Foxtail millet	PS-4, SiA-326
8.	Proso millet	TNAU-202, TNAU-164
9.	Brown-top millet	IIMR AK-2

Recently released varieties of millets

S.No	Variety	Year of release	Salient features
	Pearl Millet		
1.	HHB299	2018	Richiniron(73.0ppm)andzinc(41.0ppm)incomparisonto 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
2.	AHB 1200	2018	Richiniron(73.0ppm)incomparisonto45.0-50.0ppmin popularvarieties/hybrids
3.	AHB1269Fe	2018	Richiniron(91.0ppm)andzinc(43.0ppm)incomparisonto 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popularvarieties/hybrids
4.	ABV04	2018	Richiniron(70.0ppm)andzinc(63.0ppm)in comparisonto 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
5.	RHB233(MH2173)	2019	Highiron (83ppm)andhighZn(46ppm)
6.	RHB234(MH 2174)	2019	Highiron(84ppm)andhighZn (41ppm)
7.	HHB 311 (MH 2179)	2019	Highironcontent(83ppm)
8.	PhuleMahashakti	2018	Richiniron(87.0ppm)andzinc(41.0ppm)incomparisonto 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in

S.No	Variety	Year of release	Salient features
			popular varieties/hybrids
	Finger Millet		
1.	Vegavathi (VR 929)	2019	High in grain Zn content (199.1%). It is high in Fe, Ca, protein content, dietary fibre and low in Tannin content.
2.	CFMV 1 (Indravathi)	2020	Rich in Ca (428 mg/100g), Fe (58 mg/kg) and Zn (44 mg/kg) in comparison to Ca (200 mg/100 g), Fe (25 mg/kg) and Zn (16 mg/kg) in popular varieties
3.	CFMV 2	2020	Rich in protein (6.41%), Ca (654 mg/100g), Fe (39 mg/kg) and Zn (25 mg/kg) in comparison to Ca (200 mg/100 g), Fe (25 mg/kg) and Zn (16 mg/kg) in popular varieties
	Little millet		
1.	CLMV 1	2020	Rich in protein (14.4%), Fe (59 mg/kg) and Zn (35 mg/kg) in comparison to Fe (25 mg/kg) and Zn (20 mg/kg) in popular varieties
2.	SreeNeelima	2020	Rich in anthocyanin (50.0 mg/100g), crude protein (15.4 %) and zinc (49.8 ppm) in comparison to negligible anthocyanin, 2.7 % crude protein and 22-32 ppm zinc in popular varieties

(B) Package of Practices

It is important to adopt scientifically proven and recommended package of practices to grow a good millet crop.

Crop	Sowing time	Seed treatment (g/kg)	Seed rate (kg/ha)	Spacing (cm)	Nutrient (kg/ha) N:P:K	Irrigation
Pearl millet	Onset of monsoon	Trichoderma@4, Thiram @3, metalaxyl@6	3-4	45 x 15	60:30 $ZnSo_4$-10	Tillering, flowering, grain development
Sorghum	Onset of monsoon	Imidacloprid@5 + Carbendazim@2	7-8	45 x 15	60-80:40:20	Tillering, flowering, grain development
Finger millet	June-July	Thiram@2.5	4-5 (TP), 8-10 (DS)	30 x 10	60:30:30	Tillering, flowering, grain development
Kodo millet	June-July	Ceresan@3	10	30 x 10	40:20:20	25& 45 DAS
Barnyard millet	June-July	Ceresan@3	10	25 x 10	40:20:20	25& 45 DAS

Crop	Sowing time	Seed treatment (g/kg)	Seed rate (kg/ha)	Spacing (cm)	Nutrient (kg/ha) N:P:K	Irrigation
Foxtail millet	July-August	Ceresan@3	8-10	30 x 10	40:20:20	25& 45 DAS
Little millet	June-July	Ceresan@3	6-8	25 x 10	40:20:20	25& 45 DAS
Proso millet	Onset of monsoon	Thiamethoxam @4	8-10	25 x 10	40:20:20	25& 45 DAS
Brown-top millet	April-August	Thiram@2.5	5	25 x 10	40:20:20	25& 45 DAS

(C) Intercropping

Millet crops are an important component indiversification of cropping systems through intercropping. When intercropped with leguminous crops the soil fertility is sustained.

Crop	Intercropping
Pearl millet	With blackgram, pigeon pea, soybean
Sorghum	With pigeon pea/soybean/greengram 2:1
Finger millet	With soybean (4:1), pigeon pea (6:2)
Kodo millet	Kodo millet + greengram/blackgram/ soybean in 2:1
Barnyard millet	Barnyard millet + rice bean in 4:1
Foxtail millet	With groundnut (2:1), cotton & pigeon pea (5:1)
Little millet	With soybean,blackgram pigeon pea in 2:1
Proso millet	With greengram 2:1
Brown-top	With sunflower, maize, soybean

(D) Insect and disease management

Pest management is very important to protect the millet crops and reduce the loss caused in yields.

Crop	Insect-pest	Control	Disease	Control
Pearl millet	Shoot fly, Stem borer, white grub	Imidachloprid@ 300 ml/ha, Carbofuron@ 12 kg/ha, Quinalphos@4 g/L	Downy mildew, Blast, Smut, Ergot Rust	Seed treatment D-M-45@0.2%
Sorghum	Fall army worm Stem borer	Spinetoram 11.7 % SC @ 0.5 ml/L or Chlorantraniliprole 18.5 @ 0.3 ml/L or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC @ 0.25 ml/L Carbofuron@ 12 kg/ha	Grain mold Downy mildew	Propiconazole @0.2% Ridomil@3 g/L
Finger millet	Cut worm,	Quinalphos@ 1.5 ml/	Blast	Seed treatment

Crop	Insect-pest	Control	Disease	Control
	aphid, stem borer	L, Dimethoate@ 1.5 ml/L, Metasystox @ 2 ml/L	Brownspot	mancozeb@0.2 %
Kodo millet	Shoot fly	Carbofuron @20 kg/ha	Rust Head smut	Mancozeb@0.2 % Seed treatment
Barnyard millet	Shoot fly, stem borer	Carbofuron @20 kg/ha	Smut	Seed treatment
Foxtail millet	Shoot fly	Carbofuron @20 kg/ha	Downy mildew, Rust	Ridomil@3 g/l, Mancozeb @ 0,2%
Little millet	Shoot fly, Shoot borer	Carbofuron @20 kg/ha	Smut	Seed treatment
Proso millet	Shoot fly	Seed treatment thiamethoxan@4 g/kg Carbofuron @20 kg/ha	Head smut	Seed treatment

(E) Weed management

Crop-weed competition and yield losses

Weeds compete with crop for nutrients, soil moisture, space and sunlight. Millets are poor weed competitors in the early stage of growth. It is important to control weeds during the critical period of weed competition which is around 25-40 days after sowing/planting. If not controlled timely these harmful plants may, in general, reduce the yield of sorghum (15-83%), pearl millet (16-94%), finger millet 55-61 and kodo millet by 46%. Weed infestation causes increased cost of cultivation, reduction in the crop yields and quality of the produce.

Major weeds infesting millets

Millets are mostly grown in the *kharif*season, hence most of the rainy season weeds of the particular agro-ecological zone infest millet crops. Major among grasses are *Echinochloacolona, E. crus-galli, Cynodondactylon, Dactyloctеniumaegyptium, Brachiariaramosa, Digitarias anguinalis, Eleusineindica, Panicumreptans, Dinebraretroflexa, Paspaladiumflavidum* etc., The major broad-leaved are *Euphorbia geniculata, E. hirta, Alternantherasessilis, Physalis minima, Digeraarvensis, Commelinabenghalensis, C. communis, Amaranthusviridis, Trianthema portulacastrum, Ageratum conyzoides, Celosia argentea, Eclipta alba, Mollugopentapyhla, Phyllanthusniruri, Leucasaspera, Strigaasiatica*etc., among sedges *Cyperusrotundus, C. iria, C. esculentus* are the major ones.

Weed management options

Millets are primarily grown on under-nourished soils with poor crop management. Improper agronomic practices like broadcasting method of seed sowing and fertilizer application help in abundant growth of weeds. Weeds in these crops are mostly managed by weeding once at the early growth stage. Herbicide use is restricted due to non-availability of selective herbicides in millets. Different weed management options in millets could be:

i. Preventive methods

In principle, the crop seed for sowing should be free of weed seeds. The compost used should be well rotten so that weed seeds are killed in the process of composting. The filed bunds etc. should be kept weed free and emphasis should be to remove the weeds before they set seeds for the next generation.

ii. Stale seed-bed

This is an effective practice for controlling the first flush of weeds. 10-15 days before sowing the crop a light irrigation may be given to germinate the weed seeds which are killed by either herbicides or light inter-culture operation. Afterwards crop sowing is done without much disturbing the soil.

iii. Crop row spacing

Sowing the crop in lines helps easy removal of weeds by mechanical tools. Narrow row spacing also helps the crop to cover the soil surface quickly thereby reducing the weed germination.

iv. Mulching

Mulches of crop residues may be used to cover the soil surface in between the crop rows. This restricts sunlight to reach the soil surface which does not allow weed seeds to germinate.

Finger millet crop mulched with wheat straw

v. Intercropping with legume crops

Intercropping is an effective tool for weed suppression. The sorghum and pearl millet may be intercropped with short statured legume crops viz. blackgram, greengram, soybean as a soil cover to minimize weed infestation. Small millets may be intercropped with pigeon pea in 6:1 ratio.

vi. Inter-culture/weeding

Millets are grown at row to row spacing of 30-40 cm, hence suitable weeding tools like wheel hoe, hand hoe can be utilized for weeding purposes at least twice i.e., at 20 and 40 DAS/DAT. Similarly, two hand weedings done at 20 and 40 DAS/DAT are sufficient to contain the weed growth. Stale seed-bed, mulching and herbicide application, is often followed by complementary mechanical or hand weeding.

vii. Herbicide use in millets

Very few herbicide recommendations for weed management in millets are available at present. In pearl millet and sorghum herbicide like atrazine (500 g/ha), pendimethalin (650 g/ha), metolachlor (700 g/ha) and 2, 4-D (500 g/ha), in barnyard millet, bensulfuronmethyl +pretilachlor (550 g/ha), in transplanted finger millet and barnyard millet, atrazine (700 g/ha), metribuzin (150 g/ha), oxyfluorfen (100 g/ha), pyrazosulfuron (20 g/ha) and 2, 4-D (500 g/ha), and metribuzin (150 g/ha), oxyfluorfen (100 g/ha), pendimethalin (600 g/ha), isoproturon (500 g/ha) and metsulfuron (4 g/ha) may be used in kodo millet.

Two hand weeding in Finger millet

Oxyfluorfen*fb* 1 hand weeding 40 DAT in Finger millet

(F) Grain yield

Better yield of millets can be obtained by adopting improved varieties and recommended package of practices.

Crop	Yield (q/ha)
Pearl millet	25-35
Sorghum	25-30
Finger millet	25-30
Kodo millet	15-18
Barnyard millet	12-15
Foxtail millet	20-25
Little millet	15-20
Proso millet	15-20
Brown-top millet	7-8

Millets cultivation under natural farming

Natural farming is being promoted in India to produce healthy food grains and dairy products. It is a farming without chemicals and relies on varied farming system based on agro-ecology, that integrates crops, trees and livestock. Natural farming allows the optimum use of functional biodiversity, which encourages the use of on-farm inputs prepared by the farmers, and the indigenous breed of cow (Desi cow) are preferred and plays a vital role in natural farming system. Other cattle's dung and urine can also be used for preparation of concoctions which builds on natural or ecological processes that exist in or around farms.

Millet cultivation in hill regions, tribal regions is done without adopting chemicals for plant nutrition and pest management. However, better output can be obtained following scientifically verified practices suggested for natural farming. Millets are most suited climate resilient crops for cultivation following natural farming principles and practices. They are:

- According to natural farming principles, plants get 98% of their supply of nutrients from the air, water, and sunlight. And the remaining 2% can be fulfilled by good quality soil with plenty of friendly microorganisms. (Just like in forests and natural systems)
- The soil is always supposed to be covered with organic mulch, which creates humus and encourages the growth of friendly microorganisms.
- Farm made bio-cultures named 'Jeevamrit, Beejamrit etc.' are added to the soil instead of any fertilizers to improve microflora of soil. Jeevamrit, Beejamrit are derived from very little cow dung and cow urine of desi cow breed.
- It holds the promise of enhancing farmers' income while delivering many other benefits, such as restoration of soil fertility and environmental health, and mitigating and/or reducing greenhouse gas emissions.
- The system requires cow dung and cow urine (*Gomutra*) obtained from Indian breed cow only. Desi cow is apparently the purest as far as the microbial content of cow dung, and urine goes.
- In natural farming, neither chemical nor organic fertilizers are added to the soil. In fact, no external fertilizers are added to soil or given to plants whatsoever.
- In natural farming, decomposition of organic matter by microbes and earthworms is encouraged right on the soil surface itself, which gradually adds nutrition in the soil, over the period.
- In natural farming there is no plowing, no tilting of soil and no fertilizers, and no weeding is done just the way it would be in natural ecosystems.
- Natural, farm-made pesticides like *Dashparni ark* and *Neem Astra* are used to control pests and diseases.
- Weeds are considered essential and used as living or dead mulch layer.
- Multi-cropping is encouraged over single crop method

Conclusion

Increasing awareness about health and importance of millets in human nutrition and sustainable food system, the concept of "One Health" is globally promoted. As the millets are nutritionally rich and climate resilient crops, they will play a major role in future food sustainability. There is a need to recreate the demand of millets in our food system. Millets, especially minor millets are still grown by small and marginal farmers with low or no external inputs or by default under natural/organic farming in some of the tribal areas, the cultivation of these crops can be easily converted under natural farming by creating awareness, improvement in production technologies, processing, value addition and linking with the market. So that with tagging their products as Natural/Organic product, even with the low productivity the farmers could get higher premium price. By this way more and more farmers will be encouraged to grow the millets.

LEAD PAPERS

THEME-III

"TRANSFORMING MILLETS TO MAJOR EXPORT COMMODITY"

SUSTAINABLE TRANSFORMATION OF MILLETS SUPPLY CHAIN TOWARDS MAKING INDIA AS GLOBAL MARKET LEADER

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Millets have been integral Part of Indian diet for centuries. Millets can be grown in poor soil conditions with less water, fertilizers and pesticides. It contains comparative advantage over other cereals in terms of soil, climate adaptability, drought resistance and insect, pest-tolerance etc. Further the health and nutritional properties of millets play an important role in tackling food security and malnourishment problems in many countries.

India is one of the leading producers of millets in the world with an estimated share of around 41 percent in the global production. India's top five millet producing states are Rajasthan, Maharashtra, Karnataka, Gujarat and Madhya Pradesh.

India is among top 5 exporters of millets in the World. World export of millets has increased from $400 million in 2020 to $470 million Dollars in 2021. India exported millets worth of around 64 million dollars in the year 2021-22, against 59.75 million dollars in the year 2020-21. The major millet importing countries in the world are Indonesia, Belgium, Japan, Germany, Mexico, Italy, the US, the UK, Brazil and Netherlands. India mainly exports to UAE, Nepal, Saudi Arabia, Libiya, Oman, Egypt, Tunisia, Yemen, the UK and the US.

The export share of millets from India is around 1% of total millets production. The exports of millets from India mainly include whole grain and the export of value-added products of millets is negligible thus there is huge scope for increasing the export share of Indian millets in global markets both in the form of whole grain as well as processed millet products.

The multi-pronged strategies around sustainable millets supply chain development through increased production and productivity, value addition/processing, certification, traceability as well as promotion of uniqueness of Indian millets in the potential export markets need to be promoted. This would contribute towards the sustainable transformation of millets supply chain in India, while making India as global market leader.The Centre has created the Nutri Cereals Export Promotion Forum to give impetus to the export of potential products, including millets, and to remove the bottlenecks in the supply chain of nutri-cereals.The Government of India has also formulated an action plan to promote exports of millets and value-added products of millets, which will boost the demand of Indian millets in the international markets.

Solidaridad being the global civil society organization with around more than 50 years of experience in sustainable supply chain development across various global commodities would also be contributing through its knowledge and best practices towards making India as global market leader in the export of millets and millets-based products.

Key Strategies for Sustainable Transformation of Millets Supply Chain towards Making India as Global Market Leader

We suggest following key strategies for making India as a global market leader in Millets

1. **Sustainability Standards for Millets:** A common sustainability standard is to be prepared in order to fulfill the growing demand of sustainable, environment friendly and safe food products especially in global markets. By creating such standards for millets and millets-based products, India may leverage the advantages of first mover.
2. **Millets Clusters Developmentfor the Increased Production and Productivity:**the potential clusters are to be developed for the increased production of qualitative and cost-effective millets. The increased production and productivity would lead towards the income enhancement of farmers and also it would contribute towards the price competitiveness to the Indian millets and millets-based products. This would contribute towards establishing India as a consistent supplier of quality and price competitive millets products.
3. **Private Sector Engagement for Processing and Value Addition:** The private sector players are to be encouraged for the establishment supply chain around procurement of millets from farmers/FPOs, its processing and value addition with the key focus to cater the needs of export markets as well as domestic markets. The FPOs / entrepreneurs are needed to be supported for post-harvest value addition and branding of millet products in the domestic as well as global markets.
4. **Traceability Tools and Solutions:** Sustainability without traceability is an incomplete idea. Agri-businesses worldwide are scurrying in that direction as sustainability and traceability take centre stage on consumer palates. With growing demand for assurance on taste, quality, nutrition, safety and sustainability, ingredient provenance and brand story are becoming key areas of exploration for agribusinesses. Traceability tools are to be designed to bring transparency within the supply chain. The traceability tool would tell the entire journey of a commodity to finished food product, from the production (farmer) to the destination (consumer) and compliance to impact. It will not only empower supply chain actors at different stages to define their claims on safety, quality and authenticity of their produce, but also enables them in fulfilling their commitments towards social, economic and environmental sustainability.
5. **Common platform for key Importing Countries:**A common platform is to be created with the leadership of India and it would engage representatives from key importing countries. The platform would facilitate dialogues on common areas of interest, enabling policies and trade negotiations etc. The platform would involve stakeholders of the supply chain such as government, businesses, trade bodies/associations, FPOs, Start-ups, exporters, producers of millet-based value-added products etc. It would also support the India's export forum for millets through sharing of information related to export trends, potential of various millet value added products etc. It would also help in promotion of uniqueness of Indian millets in the potential export markets.

   Overall, this would contribute towards the sustainable transformation of millets supply chain in India, while making India as global market leader.

About Solidaridad

Solidaridad is an international civil society organization with 53 years of experience in developing solutions to make communities more resilient and create more sustainable supply chains .Our solutions support the transition to an inclusive economy that provides sustainable livelihoods with fair and profitable business opportunities .This includes decent working conditions, a fair living wage and production in balance with nature. We work through eight locally managed Regional Expertise Centres across five continents and 44 countries worldwide.

For the past 50 years Solidaridad has engaged government policy makers and private sector partners, and is considered a thought leader and innovator in the field of sustainable supply chains and trade of various agro-commodities.

Solidaridad is pioneer in the sustainable supply chain development. In 1988, Solidaridad initiated Max Havelaar coffee: the Dutch name of what became the Fairtrade certification and labelling on a global scale. In the decades to follow, Solidaridad was at the forefront of the development of various certification programmes. These were new concepts that follow the Solidaridad pyramid of change model, as designed by Solidaridad in the mid-2000s.

Solidaridad has strong presence through various field programmes in India. We are Pioneer in leveraging partnerships towards enhancing the livelihood of Smallholders farmers through market driven solutions. We bring together supply chain actors and engage them in innovative solutions to improve production, ensuring the transition to a sustainable and inclusive economy that maximizes the benefit for all.

We bring together supply chain actors and engage them in innovative solutions to improve production, ensuring the transition to a sustainable and inclusive economy that maximizes the benefit for all. Solidaridad through its commodity-based sustainability supply chain programmes is directly contributing poverty alleviation by supporting producers in sustainable crop production and market access. These programmes aim to improve crop productivity per unit area and profitability of farming using sustainable agriculture practices. Also, programmes envisage balancing economic, environmental, and social aspect of crop production. In addition to this, programmes also create market access to farmers and their families to ensure appropriate market price and cash flow in time enabling them to live with dignity by farming.

MILLETS AS NUTRACEUTICALSAND ECOSYSTEM FOR TRANSFORMING MILLETS TO MAJOR EXPORT COMMODITY

SS THORAT

Ex. Head,Dept. of FST, MPKV, Rahuri andNodal Officer,Govt. College of Food Technology, Kashti,Malegaon, MPKV, Rahuri

Millets are one of the oldest agronomic groups of grasses that serve as a nutritious staple food in Asia and Africa. The millet variants are particularly suited to the Indian climate, due to their resilience and ability to grow under marginal soil fertility and moisture conditions. Before the Green Revolution in India in the mid-1960s, small millets made up more than 40% of all cultivated grains in an agriculture industry that contributed more than 50% to the Indian GDP. Millets, a group of highly nutritious food, have taken a back seat in the Indian agriculture landscape till last decade. But in recent years, due to government policies and nutritional importance and value chain these millets are getting importance.

Food security and Global distribution of millets

Millets are grown in more than 130 countries and are eaten by more than 500 million people in Asia and Africa.Millets are sustainable food source for combating hunger in a changing world climate. Millets secure sixth position in terms of world agricultural production of cereal grains and are still a staple food in many regions of the world and can be useful as a sustainable means for nutritional security. These are rich source of many vital nutrients and hence, promise an additional advantage for combating nutrient deficiencies in the third world countries. Millets are resistance to climatic stress, pest and diseases and can be stored for long with ease.

Naturalnutraceuticals in millets

The evidence shows that an unhealthy diet and insufficient physical activity are among the major causal factors in coronary heart disease, cerebrovascular strokes, several forms of cancer, type 2 diabetes, hypertension, obesity, osteoporosis, dental caries, and other conditions.Noncommunicable diseases (NCDs) kill 41 million people each year, equivalent to 74% of all deaths globally. Each year, 17 million people die from a NCD before age 70; 86% of these premature deaths occur in low- and middle-income countries. Of all NCD deaths, 77% are in low- and middle-income countries. Micronutrient deficiencies (MNDs) are common, affecting an estimated 2 billion people worldwide.

Millets have low Glycemic Index and are rich in bioactive compounds and essential amino acids. They are also rich in micronutrients like calcium, iron, zinc, iodine etc. They are three to five times more nutritious than wheat and rice in terms of proteins, minerals and vitamins. Millets can help combat cardiovascular diseases, anaemia, calcium deficiency etc. Millets are considered to be the next super food or ‘nutri-cereals’ of the world because of their high nutritional content.

The seed coat of the millet is excellent source of phytochemicals such as polyphenols and dietary fiber. Now a days, polyphenols considered as “life span essential” due to their role in

maintaining body functions and health throughout end phase of the life. Millet polyphenols is a complex mixture of cinnamic acid derivatives and benzoic acid, perform enzyme inhibitory and anti-cataractogenic activities. Main polyphenols such as phenolic acid and tannins are present in cereals whilst flavonoids are present in small quantities. These compounds have no known direct role in nutrition but have some health friendly properties like anti-nutrients. anti-oestrogenic, anti-mutagenic, anticarcinogenic, antiviral effects, anti-inflammatory, platelet aggregation inhibitory activity that might be potential benefit in minimizing and preventing the incidence of diseases.

Phytates, polyphenols and tannins of millet's foods can contributed to anti-oxidant activity that play important role in health, aging and metabolic disease. Millets are staple food substitutes for celiac patients because they have gluten-free properties. Antioxidants acted as lipid stabilizers and as suppressors of oxidation process that causes ageing and cancer. The level of lipid peroxides, enzymatic (glutathione, vitamin E and C) and non-enzymatic antioxidants (superoxide dismutase, glutathione peroxidase, glutathione reductase and catalase) were reduced in diabetic animals and restored to normal levels in the millet-fed groups.

Processing of millets

Millets are neither ready-to-eat nor ready-to-cook grains and invariably need some kind of processing for human consumption. Three major components of millets i.e. protective pericarp, starchy endosperm, and germ gets partially separated or modified during processing. Some millets require multiple processing for optimization of grain recovery and optimization of polishing to retain their nutrition value. The grains vary in terms of shape, nature of grain surface, hardness, husk-grain bonding etc. Furthermore, there are variations within the same small millet crop due to variation in varieties, cultivation practices, and microclimate across production regions.Several processing methods like decortication, heating, soaking, germination, and fermentation can reduce the content of anti-nutrients such as tannins, phytates, trypsin, amylase inhibitors, etc. Usually, anti-nutrients don't have any significant harmful effect on an individual's health.

Processing of millet grain initiates with husk removal as it consists of a hard seed coat. Cracked or broken grains, coarse meal, grits, and fine flour are the products of dry-milled whole grain. Millets can be processed into flour, and porridges and grains can be puffed, salted, germinated, roasted, and malted. The flour can be used as it is or by mixing with other flours to produce simple to complex food products.Processed Millets (like millet flour) have poor shelf life due to its intrinsic enzyme activity (lipase activity, lipid oxidation etc.) that causes rapid development of rancidity and bitterness. Millet products are also prone to moisture and water activity.

Value-added products of millets

In India, the main food products of millet are roti, porridge, and mudde. Millet flour tastes mild and has a slightly chewy texture. Bread, pizza crusts, pancakes, and other baked goods can all be made with millet flour. It is also useful for thickening soups and stews. Multigrain flour/composite flour is made by blending millet flours and pulses which are rich in nutrients such as protein, minerals, vitamins, and dietary fiber. Millet malt is rich in minerals, sulphur and amino acids and forms an ideal base for formulations of weaning food.

In South India, papad is a conventional product, made by mixing finger millet flour up to 15-20% with other ingredients such as spice, rice, and black gram dal. Idli and dosa are fermented food commonly used for breakfast and also in evening meals in India can be completely substituted by millet in place of rice. Popped grain is a porous, pre-cooked, and crunchy product that on the addition of flavour gives a good taste.Extrusion cooking is one of the most efficient and versatile food processing technologies that can be used to produce pre-cooked and dehydrated food products such as snacks food, baby foods, breakfast cereals, noodles, pastas and cereals based blends. Fryums are the best example of extrusion technology. Energy/Food bars are considered as snack food, with good sensory and nutritional characteristics due to their high content of proteins, carbohydrates, vitamins, and minerals. The consumption of cereal bars has increased mainly among young consumers. As millets are low-cost, nutritious, and locally available indigenous food, millet flour bars, popped millet bars and fortified millet bars are gaining importance in the global market.

Many research institutes have developed bakery products like bread, biscuits, cakes, nankhatai, cookies and muffins using foxtail, finger, barnyard, proso and pearl millets added with wheat flour.

Millet based probiotic beverages

Probiotics are defined as live microbes that are beneficially affect the host by improving its intestinal microbial flora when administrated in adequate amounts. It aids the existing flora or helps to repopulate the colon when bacteria levels are reduced by antibiotics, chemotherapy or diseases. Most of the probiotic foods provides fatty acids, vitamins and other vital nutrients that improve the body`s resistance against pathogenic microorganisms and in addition leads to several health benefits including the reduction of level of serum cholesterol, the improvement of gastrointestinal function, the enhancement of the immune system, the suppression of diarrhoea in young children and the lowering of the risk of colon cancer.

Traditional millet-based products

Millets are consumed as flat bread, porridge, roasted and alcoholic and non-alcoholic beverages. Millet porridge is a traditional food in Indian, Russian, German and Chinese cuisines. Millets are also used to replace commonly used cereals in local dishes like *idli*, *puttu*, *adai*, *dosa, dhokla* etc. Other traditional products like *baddis, halwa, burfi, papad* with added millet are also reported in literature. Non-alcoholic likeAppalu, Samaipayasam, Korramurukuluetc and alcoholic beverages likeSur, Madua, Oshikundu, Koozhetc are prepared using millets.

Ecosystem for transforming millets to major export commodity

1. **Millet exports**

India is among the top 5 exporters of millets in world. World export of millet has increased from $400 million in 2020 to $470 million in 2021 (ITC trade map) India exported millets worth $64.28 million in the year 2021-22, against $59.75 million in 2020-21.

India, Nigeria and China are the largest producers of millets in the world, accounting for more than 55% of the global production. India is one of the leading producers of millets in the world with an estimated share of around 41 per cent in the global production. India produced more

than 13.71 to 18 million tons of millet with the highest production in 2020-21. The fourth advance estimates for the year 2021-22 said that about 16 million tons of millet was produced in India, which is about 5 percent of the national food grain basket. As per the DGCIS data, India registered a growth of 8.02% in the export of millets in the financial year 2021-22 as the export of millets was 159,332.16 metric tonne against 147,501.08 metric tonne during the same period last year. India's major millet exporting countries are U.A.E, Nepal, Saudi Arabia, Libya, Oman, Egypt, Tunisia, Yemen, U.K and U.S.A. The varieties of millets exported by India include Bajra, Ragi, Canary, Jawar, and Buckwheat. The major millet importing countries in the world are Indonesia, Belgium, Japan, Germany, Mexico, Italy, the U.S.A, United Kingdom, Brazil and Netherlands.

There are 16 major varieties of millet, which are produced and exported, including Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Ragi) Minor Millets (Kangani), Proso Millet (Cheena), Kodo Millet (Kodo), Barnyard Millet (Sawa/Sanwa/Jhangora), Little Millet (Kutki), Two Pseudo Millets (BuckWheat/Kuttu), Ameranthus (Chaulai) and Brown Top Millet.

2. Scheme on Initiative for Nutrition Security through Intensive Millets Promotion (INSIMP)

Government allocated Rs. 300 crores in 2011-12 under RashtriyaKrishiVikasYojana for promotion of millets as Nutri-cereals. Scheme on Initiative for Nutrition Security through Intensive Millets Promotion (INSIMP). The scheme aims to demonstrate the improved production and post-harvest technologies in an integrated manner with visible impact to catalyze increased production of millets in the country. Demonstration-cum-training centre: One processing unit along with the services of one Technical Assistant purely on contract basis were set up in selected 100 KVKs to serve as demonstration cum training centres for furtherance of post-harvest technologies.

3. Cluster approach, training and capacity building

Training and capacity building needs to take place at different levels across the value chain such as farming, farm-gate processing, value addition, commercialization, etc. Currently, the several institutes engaged in millets cultivation are engaged in training the farmers, women groups, etc., on various farming activities. There are very limited efforts going into training the public on various product technologies and recipes with millets. ICAR IIMR being nodal institutes has been organizing some training programs such as value MILLETS "The Future Super Food for India".

Recently, MoFPI has launched the ODOP program under the PMFME scheme where training and incubation for various commodities are being planned. Total 17 districts from 11 states were selected for millet based products, where training on some millet products like vermicelli, pasta, flours, etc., are being implemented. The major challenge is that several capacity-building efforts by various stakeholders such as state governments, NGOs, institutes are taking place with their limited expertise on products, as there is no central framework for collating the innovative technologies and training on them.

4. The 'One District One Product' (ODOP) initiative has identified 27 millet focus districts.Fast-emerging organic food brands are further helping mainstream millet

consumption.In 2018, Govt., declared millets as 'Nutri-Cereals', considering their 'high nutritive value' and also 'anti-diabetic properties'. 2018 was observed as 'National Year of Millets' aiming at larger promotion and demand generation. The UN General Assembly adopted an India-sponsored resolution to mark 2023 as the **'**International Year of Millets'.

The Government of India, through the revamped National Food Security Mission Operational Guidelines (NFSM), has laid specific focus on 212 millet districts in 14 states to provide incentives to farmers for quality seed production/distribution, field-level demonstrations, trainings, primary processing clusters and research support. The launch of 67 value-added technologies at the 'Centres of Excellence' has been supplemented with the release of 77 high-yielding and 10 bio-fortified varieties.

5. Agriculture and Processed products Export Development Authority (APEDA) has planned 16 programs for the promotion of millets and millet products in countries such as UAE, Indonesia, the United States, Japan, the United Kingdom, Germany, South Africa, Australia, Saudi Arabia, etc. to increase the millet exports of the country. Thus, the rising demand for millets in the global market and increased domestic production in India are anticipated to drive the market in the coming years.Exports of value-added products of millets from India are negligible.

Major importers of Indian millets: U.A.E, Nepal, Saudi Arabia, Libya, Oman, Egypt, Tunisia, Yemen, U.K and U.S.A.Bajra, Ragi, Canary, Jawar, and Buckwheat are the millet varieties exported by India.APEDA has planned to organize millet promotional activities in South Africa, Dubai, Japan, South Korea, Indonesia, Saudi Arabia, Sydney, Belgium, Germany, United Kingdom and United States of America by facilitating participation of different stakeholders from India in some of the significant food shows, Buyer Seller Meets and Road Shows. The global millets market is projected to register a CAGR of 4.5% during the forecast period between 2021-2026.The initiative is led by a partnership of Agricultural and Processed Food Products Export Development Authority (APEDA), the Indian Institute of Millets Research (IIMR) and ICRISAT. Three opportunities were presented to assist companies export millet processed products from India:

Trade exhibitions and promotion undertaken with a special Smart Food section and promotional activities and material to support this.

Distribution chain set up with an exporter, importer and distributor to help with market entry.

Product sampling and market testing undertaken in export markets

Selecting one major trade fair, implementing this initiative and then collecting lessons learnt to continue to build the initiative.Implementing research projects, including market research as well as technical research, especially to extend the shelf life of millet flour.Reviewing improvements to grading and processing standards.

Partnerships formed to popularize millets

For promotion of Indian Millets and its value-added products, centre has developed 30 e-Catalogues on each of the targeted countries comprising information on various Indian Millets and range of their value-added products available for export, list of active exporters, start-ups,

FPOs and importer/retail chain/hyper markets, etc, that to be circulated to the Indian Embassy abroad, importers, exporters, start ups and stakeholders.

As per the centre's millet promotion strategy, major international retail supermarkets like Lulu group, Carrefour, Al Jazira, Al Maya, Walmart, etc. would also be roped in to establish millet corner for branding and promotion of millets.APEDA has also created a separate section for millets on its website and the country-wise and state-wise e-catalogues have been uploaded for information to the stakeholders.

Government has also started formulating five-year strategic plan for the promotion of millets and value-added millet products in the international market in association with ICAR-Indian Institute of Millets Research (IIMR), Hyderabad, ICMR-National Institute of Nutrition, Hyderabad, CSIR-Central Food Technological Research Institute (CFTRI), Mysore and Farmer Producer Organizations (FPOs). Centre has created the Nutri Cereals Export Promotion Forum to give impetus to the export of potential products, including millets, and to remove the bottlenecks in the supply chain of Nutri cereals.

6. Branding to popularise

A brand is a name, term, design, symbol or any other feature that distinguishes one seller's good or service from those of other sellers. A brand is how a company differentiates itself from its peer brands. People recognize a company by its brand name, logo, slogan as well as colors. Branding is tailored by focusing on your target customers. It is necessary to improve marketing strategies in order to increase consumption, as well as improve recipes in order to get millets onto people's plates and to make them a regular part of their diet.

7. Millet market recent developments

The Indian Government formulated a five-year strategic plan to promote millet in the international market. The plan includes the involvement of Indian missions abroad and global retail supermarkets such as Carrefour, Walmart, Al Ruya, Lulu Group, etc., to export millets to increase domestic export millets worldwide.

8. Quality and safety standards for cereals and millets

Standard for cereals CODEX STAN 151-152, 153, 154, 1985, 170, 172, 173-1989.Govt. initiatives for development of standards through FSSAI, AGMARK and BIS and guidelines by India G.A.P.The India organic certification and use of logo by farmers and processors throughorganic certification by National Programme for Organic Production (NPOP).Centre has created the Nutri Cereals Export Promotion Forum to give impetus to the export of potential products, including millets, and to remove the bottlenecks in the supply chain of Nutri cereals.

9. Certified organic products

India produced around 3430735.65 MT (2021-22) of certified organic products which includes all varieties of food products namely Oil Seeds, fibre, Sugar cane, Cereals & Millets, Cotton, Pulses, Aromatic & Medicinal Plants, Tea, Coffee, Fruits, Spices, Dry Fruits, Vegetables, Processed foods etc. The production is not limited to the edible sector but also produces organic cotton fiber, functional food products etc. In terms of export value realization Processed foods including soya meal (61%) lead among the products followed by Oilseeds (12.85%), Cereals and millets (12.71%), Sugar (4.77%), Plantation crop products such as Tea & Coffee (2.16 %),

Spices and condiments (1.72%), Pulses (1.1%0) and others. Due health awareness consumers are searching for organic foods and ready to pay additional price.

Govt. measures to promotion of millets export

- Buyer Seller Meets (BSMs): The government has planned to facilitate participation of exporters, traders and farmers in 16 international trade expos and Buyer Seller Meets (BSMs).
- Indian missions: Indian missions abroad will be brought on board in branding and publicity of Indian millets.
- Foreign missions: Ambassadors of Foreign missions in India of the targeted countries and potential importers would be invited to showcase various millet-based products.
- Promotional activities: Promotional activities of millets will be held in South Africa, Dubai, Japan, South Korea, Indonesia, Saudi Arabia, Sydney, Belgium, Germany, United Kingdom and United States of America.
- Global platforms: Indian millets would be shown on global food platforms such as Gulfood 2023, Foodex, Seoul Food & Hotel Show, Saudi Agro Food, Belgium's Food & Beverages Show, Fine Food Show in Sydney, Germany's BioFach and Anuga Food Fair, San Francisco's Winter Fancy Food Show etc.
- Food sampling: APEDA will organize food sampling and tasting at the retail level and in key local bazaars of targeted countries to familiarize millet products.
- Start-up promotion: The government is supporting start-ups in exports of value-added products in the Ready to Eat (RTE) and Ready to Serve (RTS) category such as noodles, pasta, breakfast cereals mix, biscuits, cookies, snacks, sweets, etc.
- Other measures: Identification of international chefs as well as potential buyers such as departmental stores, supermarkets and hypermarkets for interaction and tie-ups.

HEALTH MANAGEMENT WITH MILLETS

UK PATIL

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Millets are found to be helpful with the reduction of weight, BMI, and high blood pressure. Millets creates mutual supplementation of protein, increases the amino acid content, and enhances the overall digestibility of protein. Millets are a traditional staple food of the dry land regions of the world. Millets are nutri-cereals which are highly nutritious and are known to have high nutrient content which includes protein, essential fatty acids, dietary fibre, B-Vitamins, minerals such as calcium, iron, zinc, potassium and magnesium. Millets help in rendering health benefits like reduction in blood sugar level (diabetes), blood pressure regulation, thyroid, cardiovascular and celiac diseases. However, the direct consumption millets as food has significantly declined over the past three decades. 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 favouring of supply of fine cereals at subsidized prices. It has now 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 backward integration. Now-a-days people are very conscious about their healthy living practices to overcome metabolic disorders and life style diseases. Initiatives under current International Millet Year will go a long way in millet promotion in the country, given its potential for offering nutritional security. In my talk I shall be discussing the potential role of millets in health management.

LEAD PAPERS

THEME-IV

"VALUE ADDITION, PACKAGING, MARKETING AND BRANDING OF MILLETS"

VALUE ADDITION OF MILLETS: CHALLENGES AND OPPORTUNITIES.

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Millet is a small-seeded grasses and are often termed nutri-cereals or dryland-cereals. It includes sorghum, pearl millet, ragi, small millet, foxtail millet, proso millet, barnyard millet, kodo millet, kutki, and other millets. These are known for high nutritive value having low glycaemic index. Further, millet has been one of the basic nutrients of humans for 4 thousand years in Africa and Asia and for Europe until the end of the Middle Age. Renewed Interest in consumption of millets across various countries due to its proven health benefits such as risks caused due to diabetes, obesity, and cardiovascular diseases.

Rice and wheat production are water intensive and are likely to be unsustainable, as freshwater resources are depleting around the globe. Photo-insensitive & resilient to climate change, millets are hardy, resilient crops that have a low carbon and water footprint, can withstand high temperatures and grow on poor soils with little or no external inputs. Therefore, production and consumption of millets could be one of the way to realize sustainable development goal (SDG) of United Nation for food and environment security.

On a conservative estimate about 95 percent of the global production of millets are consumed as food in Asia and Africa and the remainder between feed (seed, beer, etc.,) and waste. A large volume of millet produced, is locally grown, and consumed. The remaining produce is used to make beer, infant food, and breakfast. It is a commonly used to make breakfast products such as flakes and cereals. Millet beer is popular in African culture and is also finding a market in countries such as India and the U.S.

Breakfast cereals such as flakes and local recipes have seen an ascending trend of adoption by African and Asian population Thus, millets-based breakfast foods generated revenue over USD 2 billion in 2018 and likely to witness maximum gains due to increasing pattern of fibrous and gluten free food consumption. Revenues from sales of millets across the globe is forecast to increase from over US$ 10,000 Mn in 2017 to exceed US$ 13,500 Mn by 2022-end.

Challenges of Industrial exploitation:

1. Millets have varied shape and size including surface properties. Therefore, its processing into edible form poses challenges. Some millets require multiple processing steps and subsequent process variables to obtain higher recovery of head yield. There is need to develop efficient and less energy intensive hardware including infrastructure to process millets at farmer level and the industrial level.
2. Shelf life of milled grain in storage is very short especially at higher temperature and relative humidity. Millets have small amount of lipids and native lipids splitting enzymes (lipase) initiates rancidity, oxidation, and off-flavour. An appropriate pre-treatment to stabilize the milled product would help in enhancing the shelf-life.

3. Lack of market knowledge, limited distribution and lower price realization of unprocessed grains and wastage. Inconsistent supply chain (demand & supply) prevents its commercial viability. Lack of access to HYV seeds has led to low crop productivity. Lack of public awareness about nutritional benefits of millets undermines its utilization as a ready to cook cereal. High product prices of processed grain in comparison with largely consumed grains are acting as a hindrance for penetration in urban food market.There is a need to develop market linkage solutions to strengthen the supply of inputs (HYV seeds etc.) and outputs (distribution, market access etc.) and make people aware at large regarding the benefit of consumption of millets.

Opportunities of Industrial exploitation millets:

Majority of papers published on millets-based food products are related to the conventional food products which included bakery products, ready to eat, flakes other common household recopies. Very few papers on application of millets starch for food formulations. Recent publications on Kutkimillets(*Panicumsumatrense*) variety (JK-8) have shown it could be an excellent alternative to corn starch in number of food product formulations. Cross linked starch with amino acid improved the functionality, used in the development of hydrogel for the delivery nutraceuticals. In similar attempt was made to design kutki flour-based soup containing nano-bioconjugate of ellagitannin for personshavingstress related disease. Such attempts have paved the way for the development of pharma foods.

NUTRITIONAL PROFILE AND VALORIZATION OF MILLETS

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As an Indian, it is high time all of us realize and feel proud that our proposal was accepted in the UNGA to celebrate Millets by designating 2023 as the International Year of Millets #IYOM2023.

The global food security is at a crossroad due to over reliance on the conventional cereal crops and, loss of genetic pool and diversity consequently leading to marginalization of underutilized species. This has also led to hidden hunger – micronutrient deficiencies – which has long been overshadowed by the hunger related to calorie deficits. Millets werestated as coarse grains in the past, but are now termed as contemporarynutri-cereals. These are considered to be "future crops" as they are resistant to most of the pests and diseases and adapt well to the harsh environment of the arid and semi-arid regions. After decades of negligence, nutri-cereals are making a strong comeback in the Indian cereal's production segment. India (12.49 MT) ranks first in the global millet production (30.39 MT) (2020). These grains are the oldest, and probably the first cereal grain, known to human for domestic use.

Millets are small-seeded grains, major millet crops comprise finger millet (*Eleusinecoracana*), foxtail millet (*Setaria italic*), pearl millet (*Pennisetumglaucum*), and proso millet (*Penicummiliaceum*), while the kodo millet (*Paspalumsetaceum*), little millet (*Panicumsumatrense*), barnyard millet (*Echinochloafrumentacea*), sorghum (*Sorghum* spp.) and guinea millet (*Brachiariadeflexa*) are categorized as minor millets. In general, they exhibit a good nutritional profile containing about65–75% carbohydrates, 7–12% protein, 2–5% fatand 15–20% dietary fiber. Millets also have substantial amounts of vitamins, minerals, and phenolic compounds. These contain essential amino acids, ω-3 fatty acids, insoluble dietary fibre components (like glucoarabinoxylans, β-glucan and certain hemicelluloses) and necessary vitamins and minerals. Due to the rich nutritional profile of millets, they exhibit excellent health benefits. Phytochemicals minimise free radical damage and exhibit anti-inflammatory activity. Dietary fibre, especially insoluble part, demonstrates antioxidant activity due to the presence of certain polyphenolic compounds helping in prevention against certain degenerative diseases such as gastrointestinal disorders, cancers and neurological concerns. Furthermore, the millets exhibit hypoglycemic effects owing to their richness in polyphenolic compounds, fibers, interactive action between lipid, starch and protein, and certain intrinsic structural activities of starch found in millets.

Millets can be processed using the conventional decortication, thermal (roasting, hydrothermal and extrusion) and bioactivation (germination and fermentation) techniques for improving the nutritional and functional properties, and enhancing shelf stability. These

techniques can be used to prepare millet-based products by incorporating them singly or in combination. The use of millet-based composite flourscould is an ideal option to design foods with enhanced level of nutrients, especially for growing children and for those who are malnourished. Flour of sprouted millets, due to starch hydrolysis by α-amylase, could also reduce the viscosity of porridge.Millets are fermented to produce different food varieties, including thin and thick porridges, alcoholic and non-alcoholic beverages, and bakery products. Fermented products likeidlianddosa prepared by cooking are very famous breakfasts in India, and millet can be a complete substitute for rice in these products. Extruded products like puffs and flakes from millets can also be consumed as ready-to-eat snacks. Therefore, a variety of speciality products can be prepared using raw or processed millet flours, singly or in combination.

Thus, millets exhibit excellent potential of super grains and need to be brought into regular consumption by the food industry in the interest of nutritionally and health-conscious consumer.

EMERGING TRENDS IN PROCESSING AND VALUE ADDITION OF MILLET

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Millets are small-grained, annual, warm weather cereal. The millets offer both nutritional and livelihood security of human population and fodder security of diverse livestock population in dryland region of India. Millets are highly nutritious; they are known as health foods especially for control of diabetes and mineral deficiencies. One of the major factors for declining consumption of millets is the lack of awareness of their nutritive value and inconvenience of their preparation. Millets or nutri-cereals are high-energy foods; that were domesticated and cultivated as early as 10,000 years ago. The millets cultivation is taken up usually in degraded and marginal lands that receive very less rainfall and are poor in soil nutrient content. Seven important millets cultivated globally are finger millet, pearl millet, foxtail millet, barnyard millet, proso millet, kodo millet, and little millet. Overdependence on cereals after the green revolution and the present-day sedentary lifestyle of people has proliferated health-related disorders like obesity, diabetes, coronary diseases, gastrointestinal disorders and risk of colon, breast, and oesophageal cancer. The only way to fight back is through the introduction of nutritionally rich millets in our daily diets. Millets are unique for their richness in dietary fibres, antioxidants, minerals, phytochemicals, polyphenols, and proteins; that act as elixir to fight against health-related disorders. Recent global phenomenon of climate change has led to a decrease in the yield of major staple cereals and has paved path for introduction of millets into agriculture production system to formulate climate resilient cropping systems because millets are C4 plants with very superior photosynthetic efficiency, short duration, higher dry matter production capacity, and a high degree of tolerance to heat and drought. Keeping the above advantages of millets, the efforts have hastened to collect, conserve, and utilize germplasm of millets in breeding programs. Of late, several private and government agencies have ventured into value addition of millets to manufacture food and non-food products.

Millets are the harbinger of nutrition required for human health. Besides the diverse essential nutritional constituents like minerals, vitamins, micronutrients, etc., millet grains also contain a considerable amount of anti-nutritional constituents. The removal of anti-nutritional compounds from the particular type of millet is a mandatory requirement prior to its consumption otherwise it creates serious health hazards. Different techniques and treatments have been given to the millet grains at household level from ancient times to make them suitable for human consumption. These operations include soaking, heating, roasting, fermentation, cooking, etc. Now, days various unit operations have been standardized and optimized independently for each type of millet. All these unit operations like soaking, dehulling, grinding, roasting, puffing, fermentation, malting, etc., with appropriately designed processing equipment and machines are well-established in industries for commercial-scale processing of millets. The selection criteria for appropriate processing operation, equipment, and production scale are based on the targeted output.

Increasing demand for meeting the food requirements of future generations with drastic changes in climate, demand for renewable resources, reducing cultivable land area, increasing

population, additional health and nutrient requirements and socio-economic changes, related to the ongoing global pandemic of COVID-19, points towards the need for sustainable solutions backed by innovative technologies—providing both an opportunity and challenge to the food scientists around the world. Existing technologies need to be evaluated and gaps identified in order to make them more efficient, for processing and value addition to millets. In addition, novel technologies like air jet milling, use of microbial strains in germination and fermentation, biochemical, nanotechnology, ultrasound and gamma irradiation also need to be leveraged in order to ensure both scientific and commercial benefit to the community, especially to farming communities as well as the consumers. Millets have gained enormous attention recently for their nutrient values, gluten-free alternative, short crop period, ability to grow in adverse climatic conditions and high utility in varied food, nutraceutical and industrial. Further, acknowledging (United Nations General Assembly, International Year of Millets 2023, Resolution 75/263, 2021) the historical contribution of millets to food security, nutrition, livelihoods and incomes of family farmers and recognising the urgent need to invigorate market recognition of the benefits of millets and to promote efficient value chains the United Nations General Assembly has declared the year 2023 as the International Year of Millets.

Sorghum (*Sorghum bicolor* L.) is an important coarse cereal; mainly consumed by a large population of semi-arid zones of Africa, South America, and Asia as a staple food (Proietti et al., 2015). Though this grain is rich in phytochemicals, its consumption is often associated with weight loss (Stefoska-Needham, Beck, Johnson &Tapsell, 2015) due to low protein bioavailability, possibly due to cross-linking of proteins, when consumed in wet cooked form. The grain is also low in essential amino acids like methionine, lysine, and isoleucine. Anti-nutritional factors like trypsin inhibitors, tannin, and phytic acid are largely believed to be preventing bioavailability of nutrients from grain sorghum. It is reported that protein digestibility of sorghum grains decreases on cooking, which probably, is the reason why the traditionally sorghum consuming population shifted to high-energy cereals like rice and wheat. Moreover, grain sorghum is endowed with phenolics like tannins; the free form of which has health beneficial effects. On the other hand, the condensed tannins are known to have an inhibitory effect on the digesting enzymes. These condensed tannins characteristically bind with protein to form insoluble complexes during wet-thermal processing, besides retarding the mineral absorption; thus, limiting the bioavailability of nutrients. In many countries, a sizable number of populations consume fermented products with some type of heat processing. It is hypothesized that following an improved fermentation process, where tofu whey, a by-product and usually have a low economic value, when utilized as fermentation media, and adopting processing methods like flaking of fermented grains would improve the nutritional status of sorghum grain. The results of our study prove our hypothesis that a fermentation in plant-based fermentation media can improve the nutritional value and bioavailability of nutrients, especially amino acid of whole grain sorghum.

VALUE ADDITION, BRANDING AND ECOSYSTEM FOR MILLET PROMOTION

SS THORAT

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Millets are one of the oldest agronomic groups of grasses that serve as a nutritious staple food in Asia and Africa. The millet variants are particularly suited to the Indian climate, due to their resilience and ability to grow under marginal soil fertility and moisture conditions. Before the Green Revolution in India in the mid-1960s, small millets made up more than 40% of all cultivated grains in an agriculture industry that contributed more than 50% to the Indian GDP. Millets, a group of highly nutritious food, have taken a back seat in the Indian agriculture landscape till last decade. But in recent years, due to government policies and nutritional importance and value chain these millets are getting importance.

Food security and Global distribution of millets

Millets are grown in more than 130 countries and are eaten by more than 500 million people in Asia and Africa.World export of millet has increased from $400 million in 2020 to $470 million in 2021 (ITC trade map) India exported millets worth $64.28 million in the year 2021-22, against $59.75 million in 2020-21.India, Nigeria and China are the largest producers of millets in the world, accounting for more than 55% of the global production. India is one of the leading producers of millets in the world with an estimated share of around 41 per cent in the global production. India produced more than 13.71 to 18 million tons of millet with the highest production in 2020-21. The fourth advance estimates for the year 2021-22 said that about 16 million tons of millet was produced in India, which is about 5 percent of the national food grain basket. It has the highest market share of 9.62 million tons, followed by jowar with a production of 4.23 million tons. Ragi is another important millet, which contributes to the production of 1.70 million tons and the production of other millets is 0.37 million tons. The *NFSM*-Nutri-Cereals is being implemented in *212 districts* of 14 states.

Millets are sustainable food source for combating hunger in a changing world climate. Millets secure sixth position in terms of world agricultural production of cereal grains and are still a staple food in many regions of the world and can be useful as a sustainable means for nutritional security. These are rich source of many vital nutrients and hence, promise an additional advantage for combating nutrient deficiencies in the third world countries. Millets are resistance to climatic stress, pest and diseases and can be stored for long with ease.

Neutral neutraceuticals in millets

They are gluten free and non-allergenic. They have low GlycemicIndex and are rich in bioactive compounds and essential amino acids. Because of low GI, they are good for diabetic persons. They are also rich in micronutrients like calcium, iron, zinc, iodine etc. They are three to five times more nutritious than wheat and rice in terms of proteins, minerals and vitamins. Millets can help combat cardiovascular diseases, anaemia, calcium deficiency etc.Millets are

considered to be the next super food or 'nutri-cereals' of the world because of their high nutritional content.

The seed coat of the millet is excellent source of phytochemicals such as polyphenols and dietary fiber. Now a days, polyphenols considered as "life span essential" due to their role in maintaining body functions and health throughout end phase of the life. Millet polyphenols is a complex mixture of cinnamic acid derivatives and benzoic acid, perform enzyme inhibitory and anti-cataractogenic activities. Main polyphenols such as phenolic acid and tannins are present in cereals whilst flavonoids are present in small quantities. These compounds have no known direct role in nutrition but have some health friendly properties like anti-nutrients. anti-oestrogenic, anti-mutagenic, anticarcinogenic, antiviral effects, anti-inflammatory, platelet aggregation inhibitory activity that might be potential benefit in minimizing and preventing the incidence of diseases.

Phytates, polyphenols and tannins of millet's foods can contributed to anti-oxidant activity that play important role in health, aging and metabolic disease. Millets are staple food substitutes for celiac patients because they have gluten-free properties. Celiac disease is a syndrome characterized by damage to the mucosa of the small intestine, which caused by ingestion of certain proteins such as gliadins and glutenins of wheat gluten, that are not tolerated by celiac patient. Antioxidants acted as lipid stabilizers and as suppressors of oxidation process that causes ageing and cancer. The level of lipid peroxides, enzymatic (glutathione, vitamin E and C) and non-enzymatic antioxidants (superoxide dismutase, glutathione peroxidase, glutathione reductase and catalase) were reduced in diabetic animals and restored to normal levels in the millet-fed groups.

Processing and value addition of millets

Millets are neither ready-to-eat nor ready-to-cook grains and invariably need some kind of processing for human consumption. Three major components of millets i.e. protective pericarp, starchy endosperm, and germ gets partially separated or modified during processing. Some millets require multiple processing for optimization of grain recovery and optimization of polishing to retain their nutrition value. Processing of millets face several hurdles owing to variation in size of various millets. The grains vary in terms of shape, nature of grain surface, hardness, husk-grain bonding etc.Furthermore, there are variations within the same small millet crop due to variation in varieties, cultivation practices, and microclimate across production regions.

Several processing methods like decortication, heating, soaking, germination, and fermentation can reduce the content of anti-nutrientssuch as tannins, phytates, trypsin, amylase inhibitors, etc. Usually, anti-nutrients don't have any significant harmful effect on an individual's health.

Processing of millet grain initiates with husk removal as it consists of a hard seed coat. Cracked or broken grains, coarse meal, grits, and fine flour are the products of dry-milled whole grain. Millets can be processed into flour, and porridges and grains can be puffed, salted, germinated, roasted, and malted. The flour can be used as it is or by mixing with other flours to produce simple to complex food products.

Processed Millets (like millet flour) have poor shelf life due to its intrinsic enzyme activity (lipase activity, lipid oxidation etc.) that causes rapid development of rancidity and bitterness. Millet products are also prone to moisture and water activity.

Value-added products of millets

In India, the main food products of millet are roti, porridge, and mudde. Hot water is mixed with millet flour that partially gelatinizes the starch and imparts binding properties in the dough. For roti, the dough is flattened into thin sheets and baked on a hot metal plate. Mudde is prepared by steaming the dough and converting it into balls.

Multigrain flour: Millet flour tastes mild and has a slightly chewy texture. Bread, pizza crusts, pancakes, and other baked goods can all be made with millet flour. It is also useful for thickening soups and stews. Multigrain flour/composite flour is made by blending millet flours and pulses which are rich in nutrients such as protein, minerals, vitamins, and dietary fiber. This meets the emerging nutritional needs of people in face of preference for modern and healthy food habits, for mass feeding and social program.

Weaning food: In certain parts of India, finger millet malting is a traditional process.Malting of finger millet grains improves their sensory, nutritional, and digestibility quality and has a pronounced effect in lowering the anti-nutrients. Finger millet malt is superior in amylase activity to sorghum and other millets. The maximum activity of amylase develops after 4 to 5 days of germination. It is rich in calcium, sulphur and amino acids and forms an ideal base for formulations of weaning food.

Papad: In South India, papad is a conventional product, made by mixing finger millet flour up to 15-20% with other ingredients such as spice, rice, and black gram dal. For preparation of papad, finger millet flour is first cooked in water to gelatinize. The gelatinized dough is then rolled into thin sheets and cut into the desired size and shape, after that drying is done to achieve a moisture content of up to 7%.

Fermented foods/ Ready-to-cook mixes: Fermentation improves the taste, lowers the anti-nutritional factors, and increases the value of food in terms of calcium, fiber, and protein. Idli and dosa are fermented food commonly used for breakfast and also in evening meals in India can be completely substituted by millet in place of rice.

Puffing or popping: For preparing ready-to-eat products, puffing or popping is a simple processing technique. Popped grain is a porous, pre-cooked, and crunchy product that on the addition of flavour gives a good taste.

Extruded foods: In the processing of food, extrusion is one of the commonly adopted processing techniques by food industries which employ mixing, forming, texturing and cooking to develop a novel food product. Extrusion cooking is one of the most efficient andversatile food processing technologies that can be used to produce pre-cooked and dehydrated food products such as snacks food, baby foods, breakfast cereals, noodles, pastas and cereals based blends. Fryums are the best example of extrusion technology. Extrusion technology helps in transforming ingredients into value-added products. Extruded foods being RTE products have become a good choice as snack foods with the changing food habits. Due to changes in food habits, the demand for noodles has been increasing in India and abroad. Noodles which are

prepared by using a mixture of legume and millet flours are nutritionally balanced and can be used as weaning food or supplementary foods.

Energy bars: Food bars are considered as snack food, with good sensory and nutritional characteristics due to their high content of proteins, carbohydrates, vitamins, and minerals. Cereal bars appear due to the necessity of having a product combining easiness and nutritional quality, to either improve or substitute snacks between meals, to complement meals, or simply gain energy in a healthy way. The consumption of cereal bars has increased mainly among young consumers. As millets are low-cost, nutritious, and locally available indigenous food, millet flour bars, popped millet bars and fortified millet bars are gaining importance in the global market.

Bakery products: Many research institutes have developed bakery products like bread, biscuits, cakes,nankhatai,cookiesandmuffinsusing foxtail, finger, barnyard, proso and pearl millets added with wheat flour.These products have a significant increase in macronutrient and micronutrient composition as compared to simple wheat flour-based bakery products and also have lower glycaemic index (GI).

Ready-to-eat snack food: Hot and coldextruded products, puffed, roasted and nutribars can be prepared from millets in combination with Multigrain flours,vegetables and legumes.

Non-alcoholic like Appalu, Samaipayasam, Korramurukuluetc and alcoholic beverages likeSur, Madua, Oshikundu, Koozhetc are prepared using millets.

Millet Based Probiotic Beverages: Probiotics are defined as live microbes that are beneficially affect the host by improving its intestinal microbial flora when administrated in adequate amounts. It aids the existing flora or helps to repopulate the colon when bacteria levels are reduced by antibiotics, chemotherapy or diseases. Most of the probiotic foods provides fatty acids, vitamins and other vital nutrients that improve the body`s resistance against pathogenic microorganisms and in addition leads to several health benefits including the reduction of level of serum cholesterol, the improvement of gastrointestinal function, the enhancement of the immune system, the suppression of diarrhoea in young children and the lowering of the risk of colon cancer.

Traditional millet-based products: Millets are consumed as flat bread, porridge, roasted and alcoholic and non-alcoholic beverages. Millet porridge is a traditional food in Indian, Russian, German and Chinese cuisines. Millets are also used to replace commonly used cereals in local dishes like *idli*, *puttu*, *adai, dosa,dhokla* etc. Other traditional products like *baddis, halwa, burfi, papad* with added millet are also reported in literature.

Branding to popularise

A brand is a name, term, design, symbol or any other feature that distinguishes one seller's good or service from those of other sellers. A brand is how a company differentiates itself from its peer brands.Peoplerecognize a company by its brand name, logo, slogan as well as colors. Branding is tailored by focusing on your target customers.It is necessary to improve marketing strategies in order to increase consumption, as well as improve recipes in order to get millets onto people’s plates and to make them a regular part of their diet.

Ecosystem to promote millet production and marketing

Government allocated Rs-300 crores in 2011-12 under RashtriyaKrishiVikasYojana for promotion of millets as Nutri-cereals. Scheme on Initiative for Nutrition Security through Intensive Millets Promotion (INSIMP). The scheme aims to demonstrate the improved production and post-harvest technologies in an integrated manner with visible impact to catalyze increased production of millets in the country.

Demonstration-cum-training centre: One processing unit along with the services of one Technical Assistant purely on contract basis were set up in selected 100 KVKs to serve as demonstration cum training centres for furtherance of post-harvest technologies.

The 'One District One Product' (ODOP) initiative has identified 27 millet focus districts.Fast-emerging organic food brands are further helping mainstream millet consumption.In 2018, Govt., declared millets as 'Nutri-Cereals', considering their 'high nutritive value' and also 'anti-diabetic properties'. 2018 was observed as 'National Year of Millets' aiming at larger promotion and demand generation. The UN General Assembly adopted an India-sponsored resolution to mark 2023 as the 'International Year of Millets'.

The Government of India, through the revamped National Food Security Mission Operational Guidelines (NFSM), has laid specific focus on 212 millet districts in 14 states to provide incentives to farmers for quality seed production/distribution, field-level demonstrations, trainings, primary processing clusters and research support. The launch of 67 value-added technologies at the 'Centres of Excellence' has been supplemented with the release of 77 high-yielding and 10 bio-fortified varieties.

APEDA has planned to organize millet promotional activities in South Africa, Dubai, Japan, South Korea, Indonesia, Saudi Arabia, Sydney, Belgium, Germany, United Kingdom and United States of America by facilitating participation of different stakeholders from India in some of the significant food shows, Buyer Seller Meets and Road Shows.The global millets market is projected to register a CAGR of 4.5% during the forecast period between 2021-2026.

Govt. initiatives for development of standards through FSSAI,AGMARK and BIS and guidelines by India G.A.P.The India organic certification and use of logo by farmers and processors through National Programme for Organic Production (NPOP)Certification.Centre has created the Nutri Cereals Export Promotion Forum to give impetus to the export of potential products, including millets, and to remove the bottlenecks in the supply chain of Nutricereals.India exports most of it's Millet to United States, United Arab Emirates and Singapore and is the largest exporter of Millet in the World.

MECHANIZATION IN MILLET PROCESSING UNIT

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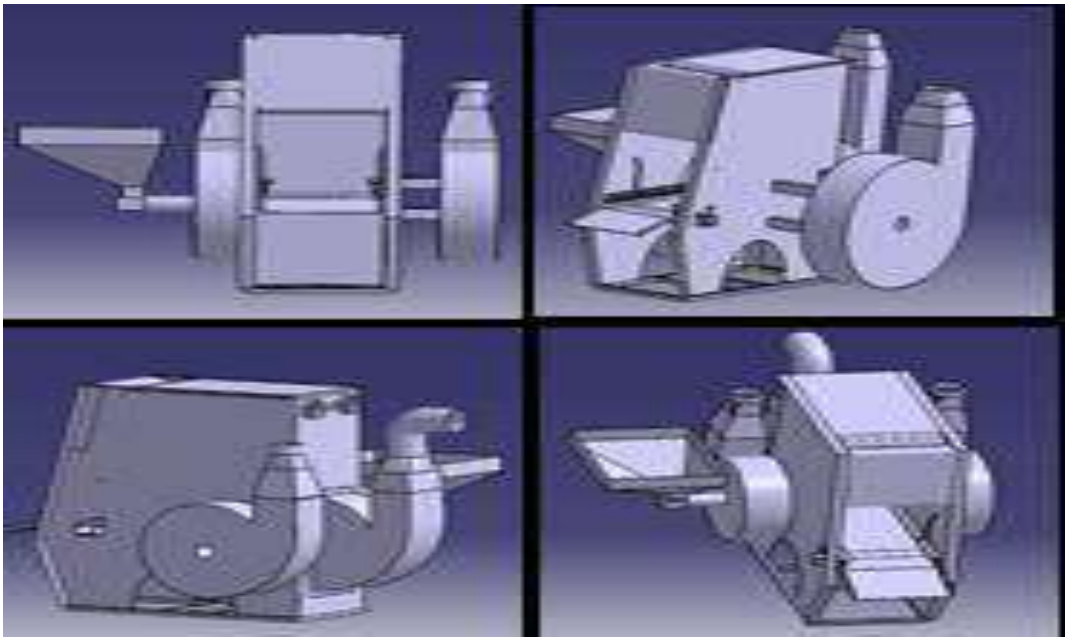
Nowadays the demand for millets is increasing day by day in the world. An increase in global demand for the consumption of millets has led to the development in production, processing and value addition. There are 9 types of millets grown in India. It is categorized into two, one is naked and the other is husked millets. Sorghum (Jowar), Pearl Millet (Bajra), and Finger Millet (Ragi) come under naked grains, and the rest millets like Foxtail Millet, Little Millet, Barnyard Millet, Kodo Millet, Browntop Millet, and Proso Millet comes under husked grains as it contains a husk layer.

Processing of husked millet is essential to make it suitable for human consumption. It starts with cleaning, grading, and removing husks using the machines as follows,

- **Precleaner with Aspirator -** Cleaning of the raw materials and other unwanted impurities**.** Aspirator channel is used to remove the lightweight materials.
- **Destoner -** Removal of the stone and mud particles present in the raw materials
- **Millet Dehuller** - Removal of the upper layer (millet husk) to get the unpolished rice
- **Gravity Separator -** Separating the improved millets rice from Grains by gravity force
- **Polisher** – Making the millet rice polished
- **Pulverizer** - It is used for the preparation of the flour, rawa etc.,

Millet-oriented companies will depend on the millet processing machinery, so it has more demand and is highly useful for Farmers, Farmer Groups, Farmer Producing Organisation (FPO), Self Help Groups, Agricultural research institutes, etc., The challenges in processing small millets are, i) variations in raw materials and ii) low shelf life of the processed small millet rice and grits due to pest infestation and rancidity. The grains of different small millet crops vary in terms of shape, nature of grain surface, hardness, husk-grain bonding, and expected rice recovery.

Large-scale processing of small millets compromises on the nutritional value of the millet rice output by obliterating the bran layer. But the pest infestation problem continues to be severe, and most processors resort to chemical methods of cleaning their products pest free. At the other end of the supply chain, the lack of small-scale processing has adversely affected the availability of the processed millets for use by the farming communities themselves. But the inherent variations in the harvested grains characteristics are significant.



Portable Double stage millet dehuller system

Vishrah Agro Tech has developed portable small-scale processing machines with the novel double stage dehuller system and process flows have been developed. The millet processing equipment is fully automated and continuous with bye pass option, from raw grain cleaning, stone removal, multi-stage shelling, multi-stage grinding and polishing, to millet grading and bagging. The process is smooth and the operations, maintenance of the equipment are convenient. The energy consumption of the new processing equipment is low and the grain touching parts is made up of stainless steel, the equipment avoids the traditional high energy consumption equipment. It is suitable for all kinds of large, medium, and small millet industries with the development of integrated portable, compact machineries with improved hopper design and hulling capacity in addition to that of the better gain flow controls.

Output recovery of the millets after complete processing (removing stones, husks, dusts. mud)

Kodo millet – 65 to 70%
Foxtail millet – 60 to 65%
Pearl millet – 75 to 85 %
Banyard millet – 60 to 65%

LEAD PAPERS

THEME-V

"NGOS AND START UPS FOR MILLET PROMOTION"

सुपर फूड–मोटे अनाज

डॉ रबीन्द्र पस्तोर
सीईओ, ई–फसल

हमारे देश में कृषि करने के तौर तरीक़ों में बहुत तेजी से परिवर्तन हो रहे हैं। भारत सरकार ने परम्परागत खेती को बढ़ावा देने के लिए अनेक नीतिगत निर्णय लिये है तथा बजट में पर्याप्त निधि आवंटित की गई है। जैविक खेती व मोटे अनाजों की खेती के उत्पादों का राष्ट्रीय व अंतरराष्ट्रीय बाजारों में व्यापार बढ़ाने के लिए अथक प्रयास किए जा रहे हैं। बदलते पर्यावरण और बढ़ती जनसंख्या की भरण पोषण की चिंता के बीच भारत के अनुरोध पर संयुक्त राष्ट्र की ओर से वर्ष 2023 को मिलेट ईयर या मोटे अनाजों का वर्ष घोषित किया गया है। अफ्रीका महाद्वीप सर्वाधिक मोटे अनाजों का उत्पादन करने वाला महाद्वीप है। यहाँ 489 लाख हेक्टेयर मे मोटे अनाजों की खेती की जाती है।

इंडियन इंस्टीट्यूट आफ मिलेटस रिसर्च हैदराबाद के अनुमान के अनुसार भारत एशिया का 80 प्रतिशत व विश्व का 20 प्रतिशत उत्पादन करता है। हरित क्रांति के बाद इन फसलों के क्षेत्रफल में निरंतर कमी आती रही है। एफएओ के अनुसार, वर्श 2020 में मोटे अनाजों का विश्व उत्पादन 30.464 मिलियन मीट्रिक टन (एमएमटी) था और भारत की हिस्सेदारी 12.49 एमएमटी थी, जो कुल मोटे अनाजों के उत्पादन का 41 प्रतिशत है। भारत ने 2021–22 में मोटे अनाजों के उत्पादन में 27 प्रतिशत की वृद्धि दर्ज की, जबकि पिछले वर्ष यह उत्पादन 15.92 एमएमटी था।

एपीडा के आँकड़ों के अनुसार मोटे अनाजों का निर्यात बड़ रहा है। ज्वार, बाजरा प्रमख निर्यातक फसलें हैं। इंडोनेशिया, बेल्जियम, जर्मनी, मैक्सिको, इटली, अमेरिका, ब्रिटेन, ब्राजील और नीदरलैंड प्रमुख आयातक देश रहे है। एपीडा द्वारा मोटे अनाजों के निर्यात को बढ़ावा देने का काम किया जा रहा है।

मोटे अनाजों के तहत ज्वार, बाजरा, कंगनी, कोदो, सावां, चेना, रागी, कुटटू, चौलई, कुटकी आदि प्रमुख पौष्टिक फसलें है। इनमें रेशे, बी–कॉम्पलेक्स विटामिन, अमीनो एसिड, वसीय अम्ल, विटामिन–ई, आयरन, मैगनीशियम, फास्फोरस, पाटेशियम, विटामिन बी–6, व कैरोटीन ज्यादा मात्रा में पाये जाते हैं। ग्लकोज कम होने से मधुमेह का ख़तरा कम होता है। इसलिए इन फसलों को सुपर फूड कहते हैं। यह फसलें कम पानी में अर्धशुष्क क्षेत्रों में उगाई जा सकती है तथा जलवायु परिवर्तन के प्रभावों के परिणाम आसानी से सहन करने की क्षमता रखती है। इन की रोगप्रतिरोधाक क्षमता बहुत अधिक होने से उत्पादन लागत बहुत कम हो जाती है।

उच्च पोषण और बेहतर स्वास्थ्य प्रदान करते हुए बदलती जलवायु परिस्थियों में जीवित रहने की क्षमता के कारण देश में मोटे अनाज को पुनर्जीवित करने के रुचि बढ़ रही है। मोटे अनाज की खेती और विपणन को बढ़ाने की दिशा में विभिन्न एजेंसियों द्वारा कई तरह की पहलों को बढ़ावा दिया जा रहा है। व्यापक प्रभाव के लिए प्रमुख प्राइवेट कम्पनियों, आपूर्ति श्रंखला के हितधारकों जैसे एफपीओ, स्टार्टअप, नियातकों और मोटे अनाजों पर आधारित गुणमूल्य संवर्धित उत्पादों के उत्पादकों के बीच एकीकृत दृष्टिकोण और नेटवर्किंग की महती आवश्यकता है।

दुनिया के अर्ध–शुष्क क्षेत्रों में भोजन और चारे के रूप में मोटे अनाज, छोटे अनाज वाले घास के अनाज का एक समूह महत्वपूर्ण है। भारत में, मुख्य रूप से गरीब और सीमांत किसानों द्वारा और कई मामला में आदिवासी समुदायों द्वारा शुष्क भूमि में मोटे अनाजों की खेती की जाती रही है। इस देश में मोटे अनाजों की खेती की पुनर्जावित करने के लिए बढ़ती रुचि पोषण, स्वास्थ्य और लचीलेपन के विचारों से प्रेरित है। ये अनाज शुष्क क्षेत्रों और उच्च तापमान पर अच्छी तरह से बढ़ते हैं, वे खराब मिट्टी, कम नमी और महँगे रासायनिक कृशि आदानों से जूझ रहे लाखों गरीब और सीमांत किसानों के लिए आसान फसलें रहीं हैं। क्योंकि उनकी कठोरता आर अच्छे पोशण की गुणवत्ता के कारण वे वास्तव में जलवायु परिवर्तन को अपनाने के लिए महत्वपूर्ण रणनीति का हिस्सा हो सकते हैं।

मोटे अनाजो के उपयोग में वृद्धि में आने वाली वाधाओं और प्रवृत्तियों को बेहतर ढंग से समझने के लिए, एम.एस. स्वामीनाथन रिसर्च फाउडेशन, एक्शन फॉर सोशल एडवांसमेंट एंड बायोडायवर्सिटी इंटरनेशनल ने 2016 और 2017 में एक अध्ययन किया, जिसमें तमिलनाडु और मध्यप्रदेश में गुणमूल्य श्रंखला में काम करने वालों को शामिल किया गया। इन फसलों के अनुसंधान और विकास दोनों में लगे प्रमुख हितधारकों के साक्षात्कार लिए गये। जिससे मोटे अनाजों की समस्याओं को समझने मे मदद मिली।

क्यों नहीं बढ़ रही मोटे अनाजों की खेती ?

मोटे अनाजों के उत्पादन में गिरावट की प्रवृत्ति के पीछे प्रमुख कारकों में कम फसल उत्पादकता, उच्च श्रम सघनता, फसल कटाई के बाद के कठिन संचालन और आकर्षक फार्म गेट कीमतों की कमी शामिल हैं। सार्वजनिक वितरण प्रणाली (पीडीएस) के माध्यम से चावल और गेहूं की आसान उपलब्धता ने बाजरा उत्पादक क्षेत्रों में खाद्य खपत पैटर्न के बदलाव में योगदान दिया है। रागी के अपवाद के साथ–जिसके लिए प्राद्यागिकी ने तेजी से प्रगति की है ।

मोटे अनाजो के हल से संबंधित कठिन परिश्रम अभी भी स्थानीय उत्पादकों को हतोत्साहित कर रहा है। अन्य अक्षम करने वाले कारकों में शामिल हैं, उत्पाद विकास, व्यावसायीकरण में अपर्याप्त निवेश, और उनके उपभोग से जुड़ी निम्न सामाजिक स्थिति की धारणा। दैनिक आहार में मोटे अनाजों का उपयोग करने के तरीकों के बारे में ज्ञान का अभाव व्यापक है, इसके बावजूद कि उनसे कई प्रकार के व्यंजन बनाए जा सकते हैं। स्थानीय बाजारों में मोटे अनाजों की खराब उपलब्धता, उनके उत्पादों की उच्च कीमतों के साथ–साथ उनकी लोकप्रियता को सीमित कर रही है।

हालांकि, सरकार के अनुसार, यह अनुमान है कि मोटे अनाजों का बाजार 2025 तक 9 बिलियन अमेरिकी डॉलर से अधिक के अपने मौजूदा बाजार मूल्य से बढ़कर 12 बिलियन अमेरिकी डॉलर से अधिक हो जाएगा।

भारतीय बाजरा को बढ़ावा देने के लिए इंडोनेशिया, जापान और यूनाइटेड किंगडम के देशों में क्रेता–विक्रेता बैठकें भी आयोजित की जाएंगी। एपोडा खुदरा स्तर पर और लक्षित देशों के प्रमुख स्थानीय बाजारों में भोजन के नमने और चखने का आयोजन भी करेगा ।

FOCUS AREAS OF PROMOTION OF MILLETS FOR NGOS AND STARTUPS

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Millets have been a neglected crop for over decades is an undisputed fact. Millets are cultivated in large acreage by resource poor, living and striving in the challenged agro-ecosystem. In Madhya Pradesh majority of the millets are grown in nutrient poor shallow and skeletal soil under rainfed condition by farmers.

Millet sub sector may be viewed under the following four sub heads to get the clear picture for developmental priorities.

Production system Constraints Marketing Processing and packaging

Production system

As mentioned earlier, millets are grown in complex diverse risk prone (CDRP) farming system. This system is predominated by the socio-economically very poor farming communities. Generally, millets are cultivated in nutrient poor, shallow and skeletal soil under rainfed condition.

The characteristics of the farming situation of millet crops are very important for the analysis of the production and productivity. The growth of any crop raised on soil that is poor in nutrients can be expected to have low indices in all the growth parameters. A stunted plant with low nutrient availability produce less, is a universal fact. Thus, the production and productivity is compromised. It is well acknowledged the importance of soil depth and rhizosphere on plant growth and yield. However, when a crop is cultivated in shallow soil with skeletal character, the root growth and the dynamics of rhizosphere is constrained. Such a situation has a negative impact on the yield parameters. Rainfed condition is another factor that decides plant growth and yield performance.

The impact of delay in rain, early withdrawal, or a dry spell during crucial crop growth stages on the overall yield of any crop is well acknowledged in scientific world. Thus, such a diverse situation is complex in the prominent millet growing areas which makes it risk prone. Finally, the uneconomical yield incompatible sustenance drives further to a stage where they resort to gradually abandon millet for an alternative during the next cropping season. This is reflected by shrinkage in the acreage of millets in recent years.

Constraints

Any production system is an economic activity. There is an input of family labour , resources at the disposal of the household and shared assets.Among millet farmers inflow cash is a major constrain. Lack of cash and accessible to credit due to their poor socio-economic situation, millet is not grown seriously with proper soil nutrient application, management of weed and soil moisture during the crop growth stages. The resultant yield is usually not encouraging to bring cheers to the millet farmers.

Cash is the outcome of a transaction of a goods or commodity. If one revisits the production system or the agro-ecosystem of millet, in the existing practices the production seldom has marketable surplus. Thus, even if selling happens its always in low volume. Millet is neither a cash crop nor is under existing MSP regime, this is another constrain besides low productivity. Millet farmers in MP being predominantly tribal farmers of small and marginal category either barter away with the produce or sell to local traders at a throw away price. Millet for them is neither a profitable venture nor assist in sustenance, yet they grow it because of their tradition or limited options.

Marketing

Marketing requires a product and a buyer. Here as mentioned either millet as a product is always in low volume available as marketable surplus among the farmers. The next disadvantageous situation is that buyers are not many therefore lack competitive pricing. In the absence of an organized millet farmers group, the commodity to be transacted or traded will remain in low quantity which means poor bargain and low-price realization to the farmers. Millet farmers live scattered along the foothills or on the hilltop, usually isolated and distantly connected with the main lane of the trade. Here, middlemen fill the space and take advantage of the situation.

Processing and packaging

Millet especially minor millets are grown organically, by default. The financial constrains compel majority of the Millet growers to restrain from application of chemical fertilizers in their millet fields. Usually, such investments on chemical fertilizers are done when the returns are higher. However, returns in the form of grain yield and cash returns from millets remained discouraging.

Having known from the statistics of chemical fertilizer consumption in such agro-ecosystems for years, it is easier to identify these geographical areas as technically organic instead of relying on the costly and time taking organic certification process. This process is followed in Northeastern States in India, the reason for delay in replicating the same process in identified areas in MP is unknown. Government of Madhya Pradesh may seriously think on these lines with strategic policy initiatives.

A small initiative towards processing of millets in Dindori district of MP is widely acknowledged and appreciated. However, much more has to be done from the learning involving different players and partners. The Department of Food Science and Technology, JNKVV Jabalpur has done quality research on millet processing, but the outcome is yet to be downloaded to the community and industry.

Packaging is highly specialized area and very important component of marketing, branding and trade. Indian Institute of Packaging needs to be drawn into millet sub sector.

The millet sub sector has a basket full of challenges and opportunities. The crop has a direct influence on the socio-economy of the poorest of poor and also the undistributed agro-ecosystem. The sector needs to develop and demands involvement of numerous players. Here comes the role of Non-Government Organization, Civil Societies and Startups. They all have different roles to play.

MARUSHAKTI–AGRI INNOVATIVE FOODS- A PROCESSING UNIT TO INSPIRE NGO AND START UP FOR MILLET PROMOTION

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Introduction

The concept of Food Security is multifaceted. Food is as essential for living as air is for breathing. But food security means something more than getting two square meals. It has following dimensions. Thus, Food security is ensured in a country only when sufficient food is available for everyone, if everyone has the means to purchase food of acceptable quality, and if there are no barriers to access.Historically, food security was seen as solution to India's nutritional problems. From the days of famine and acute food shortages, India embarked on a variety of agriculture promotion programmes and is now food sufficient. However, lately we have realized that in these efforts cereal production and distribution has got a lot of policy attention and millets got relegated.

With the changing dietary patterns the millets also took a back seat in our daily diets. This trend is often considered one of the reasons for India's current nutritional paradox where problems of under-nutrition and hidden hunger (micronutrient malnutrition even in food secure communities) co-exist. Although India is the leading producer and of millets, they have never been promoted by food and farming system and have always been marginalized both in policy and priorities of agriculture. Millets have a potential to assume significance not only for food security but also for nutritional security in India as they are rich in micronutrients like minerals and B-complex vitamins. Considering that there is increasing realization of the importance of millets, the current review aims to focus on the possible role that millets could play in promoting dietary diversification and balanced diets and suggest the way forward to use millets in addressing food and nutrition security issues in India. Millets are termed as "yesterday's coarse grains and today's nutri-cereals." Millets are considered to be "future crops" as they are resistant to most of the pests and diseases and adapt well to the harsh environment of the arid and semi-arid regions of Asia and Africa. Earliest evidence found in Indus civilization: 3000 BC. Ancient food grains first plants domesticated for food. Millets are traditional food for 59 crore people in Asia & Africa.

Different Types of Millets

The millets include species in several genera. The most widely cultivated species in order of worldwide production are:

Importance

Generally, these are rain fed crops grown in areas with low rainfall and thus resume greater importance for sustained agriculture and food security.Almost all the millets are used for human consumption in most of the developing countries but their use has been primarily restricted to animal feed in developed countries. Although millets have a diversified and high food value, their consumption, especially by the Indian populace, has not reached a significant level due to various factors. Recently, these grains have been slowly fueling the start-up revolution to improve nutri-rich food availability and create employment.Consumption of millets helps manage hyperglycemia due to their lente carbohydrate and high dietary fiber content, thus making millets a perfect food for the diabetic populace. Therefore, millets play an important role in the modern diet as a potential source of essential nutrients, especially in underdeveloped and developing countries.

Table1: Different types of millets

Classification		
Major Millets	**Minor Millets**	**Pseudo-millets**
Pearl millet (*Pennisetumglaucum*)	Barnyard millet (*Echinochloa spp.)*	Amaranth millet (*Amaranthus*)
Foxtail millet (*Setariaitalica*)	Kodo millet *(Paspalumscrobiculatum)*	Buckwheat millet (*Fagopyrumesculentum*)
Proso millet *(Panicummiliaceum*)	Little millet *(Panicumsumatrense)*	
Finger millet *(Eleusinecoracana*)	Guinea millet *(Brachiariadeflexa)*	
	Browntop millet *(Urochloaramosa)*	

(i) Benefits of millets production

- It provides nutritious food and fodder.
- It is less water consuming than other cereals.
- It grows faster & putting less stress on environment.
- It doesn't cause pests and diseases problem.
- It can grow in even marginal lands.
- It can complete food and nutritional security.
- It will help in supplementing the existing income of the farmers.

(ii) Nutritional benefits

Table2: Nutritional composition of millets (100g)

Commodity	Protein (g)	Carbohydrates (g)	Fat (g)	Crude fibre (g)	Mineral matter (g)	Calcium (mg)	Phosphorus (mg)
Sorghum	10. 4	72. 6	1. 9	1. 6	1. 6	25	222
Pearl millet	11. 6	67. 5	5. 0	1. 2	2. 3	42	296
Finger millet	7. 3	72. 0	1. 3	3. 6	2. 7	344	283
Proso millet	12. 5	70. 4	1. 1	2. 2	1. 9	14	206
Foxtail millet	12. 3	60. 9	4. 3	8. 0	3. 3	31	290
Kodo millet	8. 3	65. 9	1. 4	9. 0	2. 6	27	188
Little millet	8. 7	75. 7	5. 3	8. 6	1. 7	17	220
Barnyard millet	11. 6	74. 3	5. 8	14. 7	4. 7	14	121
Barley	11.5	69.6	1.3	3.9	1.2	26	215
Maize	11.5	66.2	3.6	2.7	1.5	20	348
Wheat	11. 8	71. 2	1. 5	1. 2	1. 5	41	306
Rice	6. 8	78. 2	0. 5	0. 2	0. 6	10	160

Millets are a highly nutritious crop and contain considerable amounts of vitamins and minerals. They are a good source of energy, dietary fiber, slowly digestible starch, and resistant starch, and thus provide sustained release of glucose and thereby satiety. Compared to cereals, millets are a good source of protein- and sulphur-containing amino acids (methionine and cysteine) and have a better fatty acid profile. On the other hand, millets contain fewer cross-linked prolamins, which may be an additional factor contributing to higher digestibility of the millet proteins.

Millets are rich in vitamin E and vitamin B and in minerals such as calcium, phosphorus, magnesium, manganese, potassium, and iron. The abundant nutrients of millets provide multiple benefits such as reducing the incidence of cancer, obesity and diabetes, cardiovascular diseases, gastrointestinal problems, migraine, and asthma.Millets are nutritionally comparable to major cereals and serve as good source of protein, micronutrients and phytochemicals.

(iii) Beneficial toecosystem

Millets can thrive at relatively high temperatures (thermophilic) and reproduce in limited water supply (xerophilic). Researches indicate the positive effect of millet cultivation in the reduction of stress on environmental resources, especially in regions affected by climate change. Looking at the water security, millets require almost six times less water for growth (20com) as compared to rice that requires average rainfall of 120-140 cm. The maturation time for certain millets is 45-70 days, half to that of rice (120-140 days). Being a C4 group of cereals, millets convert more carbon dioxide to oxygen, contributing in mitigating climate change. It can endure extremely high temperatures to drought to salinity making it a climate resilient crop.

(iv) Health benefits

- It is beneficial in treating stomach ulcers.
- It is good for heart health.
- It is beneficial due to high amount of magnesium.
- It helps in bone growth development and repair.
- It reduces cancer risk.
- It helps in weight loss.
- It controls blood sugar level in diabetes.
- It strengthens life of celiac patients.
- It contains all the essential amino acids.
- It reduces formation of gall stones.
- It bears Anti-allergic properties.
- It helps in reducing cholesterol levels.

Table3: Construction in production and consumption

Demand side factors	Supply side factors
Rapid urbanization	Increasing marginalized cultivation
Changing consumer tastes and preferences due to rising per capita income	Low profitability-low remuneration for millets.
Government policies favouring other crops such as output price incentives and input subsidies	More remunerative crop alternatives in *kharif* competing with millets.
Supply of PDS rice and wheat at cheaper price introduced in non-traditional areas of fine cereals.	Decline in production & quality - blackening of sorghum grains, fetching low price
Poor social status and inconvenience in their preparation (especially sorghum)	Lack of incentives for millet production
Low shelf-life of grain and flour.	Lack of better irrigation infrastructure

Processing of Millets

Primary processing of millets-Unit operations carried out on the grains at producers' level or in the vicinity of farm which improves grain quality / transforms the grain into more useful form.Cleaning, dehulling, sorting, polishing / pearling, grading, size reduction /grinding, drying and storage.

Secondary Post-harvest operations- Unit operations that are carried out on grain either directly or after primary processing, that transform the grain into products generally for direct consumption. They are done usually away from farm either in unorganized or in organized sectors. Puffing - the ready to eat products puffing or popping is a simple processing technique. Popped grain is a porous, precooked and crunchy product and also has a good taste by adding flavour. Baking – Baked products of millets like cakes, muffins and biscuits can be used as gluten-free options.Flaking - Quick cooking cereals. The small size of millets is suitable for flakes production.

Success story - Marushakti – Agri Innovative Foods

The climate of Rajasthan is dry due to which the things produced here have different tastes and smells.There is immense employment potential in the value addition by processing the produce of the crop obtained through horticulture.There is a need to identify such areas, crops, products and opportunities, which along with making their identity, also prove the purpose of "Vocal for Local".Marushakti has made this purpose worthwhile. It is extensively working on millets. Keeping in mind the current scenario and market needs, unit has mainly focused on value added products made out of arid foods.

LOGO OF MARUSHAKTI

Recognizing its importance and opportunities, not only the farmers but also the college students to set up their own production unit. Technology regarding increasing the shelf life of millets was developed, by which, enzymes present in it become deactivated and can be stored upto six months. Value-added millets products namely: cake, biscuits, laddu and sticks are also standardized and developed for sustainable livelihood and income generation. In these years, Marushakti has created a new identity among the people by its delicious, fresh and nutritious products. It has got FSSAI registration, adherence to hygiene and other food standards, strict adherence to all safety standards even during the Corona period were the achievements. Not only this, all the products made here are free from harmful chemicals and are completely vegetarian. These qualities make it different from other products available in the market.

- **FSSAI Registration**–22221070000974
- **UDYAM Registration**–UDYAM-RJ-08-0030043
- **GST Registration**–08AAAGC2669AIZT
- **TRADEMARK Certificate**

Technology for Millet Value Addition

Bakery products

The use of millets in bakery products will not only be superior in terms of fibre content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. These are mostly prepared from the wheat flour but efforts are being made to replace few portion of it with millets in order to provide an alternative and reduce over dependence on wheat and make gluten free bread.

However, the baking industry is mainly occupied by the different value-added products of wheat. Due to high proportion of gluten, these products are not preferred by people suffering from celiac disease especially in developed countries. Millet-based bakery products will not only be superior in terms of nutrition but will also fetch the higher price in the market. Flour of pearl millet and is preferred for making biscuits and muffins. Recently demand has increased for pearl millet-based baking products in urban /rural areas.

Millet cookies

Cookies are popular ready-to-eat product consumed by different age groups in a family. 100% millets Cookies have been prepared using the formulation of pearl millet, sorghum and finger millet flour of superior quality with addition of sugar, milk solids, trans free-fat, salt and nature identical flavouring substances.

Advantages and uniqueness of technology

- Pure Millet biscuits are fiber rich and beneficial for all age groups.
- Low sugar and low fat compared to the market products.
- It is rich in magnesium, zinc, iron, dietary fiber and protein.
- It has a shelf life of 3 months

Millet cakes

Cake is a RTE product which is prepared by mixing a mixture of flour, sugar, fat and flavoring ingredients until the mixture gets converted into dough, which is followed by baking the dough. Millet cakes have been prepared using 100% pearl millet flour and adding superior quality fat, sugar and chocolate/vanilla essence.

Advantages and uniqueness of technology

- Millet cake is fiber rich and beneficial for all age groups.
- Utility as snack food or breakfast food It is rich in magnesium, zinc, iron, dietary fiber and protein.
- It has a shelf life of 1 week at low temperature when packed in MET packets.

Millet laddu

Laddu an Indian sweet made from a mixture of flour/semolina, powdered low calorie sugar, and shortening, which is shaped into a ball. Millet laddu mix is developed from pearl millet flour adding to it powdered low calorie sugar, roasted groundnuts, dry fruits and cardamom are added. The mix has to be mixed with ghee or milk to make round balls before serving.

Advantages and Uniqueness of technology/Product

- Instantly laddus can be prepared with added flavor and taste.
- It is Gluten Free and safe for Celiac Patients.
- Rich source of phenolic compounds and causes satiety resulting in slower digestibility.
- Reduces oxidative stress (Antioxidant) Contains low calorie sugar and promotes healthy digestion by presence of dietary fibre.
- It fights against Arthritis and Rheumatism Shelf life resulted in three months when stored at ambient temperature.

Millet khakhra

Khakhra is a crispy version of roti, it is usually a cracker that is handmade and roasted to provide crunchiness. It is also a healthy snack which is a common recipe in the Rajasthani and Gujarati cuisines.

Khakhra when prepared by using finger millet as a major ingredient provides a much more nutrition in terms of protein, carbohydrates, minerals and dietary fibers in comparison with the traditional khakhra that is made of wheat flour.

Millet flour

Multigrain flour/composite flour is made from blended flours of millets, and pulses, is rich in nutrients such as protein, minerals, vitamins, and dietary fiber.It can meet the emerging nutritional needs of people in face of preference for modern and healthy food habits for mass feeding and social program. The use of sorghum rich multigrain flour offers a good opportunity to improve the taste and nutritional quality of sorghum roti.

Millet extruded snacks

Extruded Snacks are Ready-To-Eat products prepared using hot extruder which combines heating with the act of extrusion to create a shaped cooked product through a round, minus shaped dies. Commercially most of the extruded snacks are prepared from corn, here the extruded snack is made from millets. The snack can be coated with desired spices to create variations in the taste and flavour.

Conclusion

Hence an effort was made to increase the utilization of millets in popular foods which would find ready acceptability with the tag of 'HEALTH FOODS'. Millet based value added products including traditional recipes, bakery products, were developed by “Marushakti”.

LEAD PAPERS

THEME-VI

"CONSERVATION OF LANDRACES OF MILLETS"

INFORMAL SEED CHAIN SYSTEM OF FARMER'S VARIETIES FOR ENSURING SEED, FOOD AND CONSERVATION OF BIODIVERSITY

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Introduction

The ever-increasing population and over industrialization and decrease in arable land are increasingly putting pressure on the farmer side to produce more and more. The number of hungry and malnourished people will continue to rise and outpace food production, resulting in a food-insecure world. The majority of the world's one billion undernourished people reside in Asia or sub-Saharan Africa and depend daily on small farm output for their livelihood and food. Therefore, the essential focus of present–day food security concerns is resource poor and small holder farmers in developing or emerging economies. To meet the growing demand the output of these farms needs to be increased. The farm output is dependent upon many inputs, of which seed is one of the most critical. Seeds are the most essential and primary input in sustainable crop production ensuring food security and rural development. Without continuous availability or accessibility to quality seeds, many households in developing nations are exposed to the potential of becoming food insecure. Hence, the use of quality seeds and other inputs and matching cultural practices effectively increases crop production and productivity. Seeds are genetic resources that carry plant genetic diversity to the next generation. For centuries, plant genetic diversity has been traditionally developed and protected by farmers. Additionally, traditional on-farm seed saving has been responsible for establishing and conserving diverse plant genetic materials, thus, larger gene pools.

Farmer-produced seed is the most important source of planting materials in this world. Seed and other propagation materials are produced on-farm and are not part of formal seed sector arrangements, e.g., contract production, usually associated with farmers' or local seed. All of the activities related to farmers' seed production and supply are commonly referred to as traditional (Cromwell et al., 1992), local (Almekinders et al., 1994; Louwaars& van Marrewijk, 1996), or farmers' seed systems (Almekinders&Louwaars, 1999). Depending on the crop and country, 60-100% of the seed planted in developing countries is farmer produced and exchanged. When no formal sector breeding or seed supply exists, such as for indigenous vegetables and root crops like yam and sweet potato, farmers' seed is usually the only source of planting material. The importance of farmers' seed is the maintenance of varieties by farmers, including improved and local varieties.Ingeneral, farmers' seed systems have not been considered by the formal seed sector and policymakers as a part of the seed sector. The advent of high-yielding varieties has led to the disappearance of farmer's varieties and landraces because of, (i) acute shortage of quality seeds and (ii) high yielding varieties have been widely disseminated and adopted. Further, due to the lack of a proper seed system, technical and financial support from public institutions, the farmer's seed system operating at present is comparatively poor in terms of seed quality as compared to the formal seed system. Therefore, the maintenance of plant genetic diversity lies in

the hands of traditional small-scale farmers who continue to cultivate a broad range of crop species and landraces.

Farmers are adopting new and improved varieties to get higher yields. If we look into the tribal districts of central India, these farmer's varieties are still in cultivation. However, due to the lack of adoption of principles of seed production technology in cultivation, these varieties are gradually deteriorating since evolution. Due to the loss of genetic purity, they lose their unique identity and productivity. Because of these varieties' continuous deterioration and admixtures, they fail to fetch premium prices in the market, which leads to huge economic loss for the farmers. To protect and conserve these premium demand-driven farmer varieties and make their quality seeds available to the farming community, we urgently need to develop the seed chain of these farmers' varieties through scientific intervention and support from the seed technology experts of formal academic institutions. The European countries are already operating such systems as an alternative to formal seed chain systems. The initial process involved developing a seed chain system of traditional farmers' varieties in the farmer's participatory model to collect farmer's varieties (FV) from their originating area. Then, further characterization of FV based on unique morphological characters followed by maintenance breeding to generate the stock seed. Afterward, the generation of stock seed will be advanced for two stages (stage I and stage II) for seed multiplication to ensure the availability of quality seeds to the farmers.

It is necessary to develop the seed chain system of these farmers' varieties through capacity building of farmers on various aspects of quality seed production. The idea is to develop a sustainable and effective seed chain system of farmer's varieties in farmer's participatory mode. Farmer seed system of traditional farmers' varieties will be developed through the dissemination of technology and capacity building of farmers on maintenance breeding, seed production technology, seed priming technology, post-harvest handling, seed storage management, seed processing, and village-level seed production programs. These types of systems aim at the collection and characterization of farmers' varieties of the proposed crops predominantly cultivated by the tribal farmers of the identified districts, capacity building of Field Technology Incubators and Pilot Farmer on maintenance breeding and quality seed production technology of identified farmer's varieties of proposed crops in farmers field under organic environment, establishment of Farmers Seed System through farmer's participatory mode for multiplication and distribution of identified farmer's varieties of proposed crops under an organic environment in each pilot village of identified districts.

Public seed sector programme started in India during 1970-80s targeted the development of formal seed system and hence; the dissemination of certified seed of improved varieties leading to the gradual disappearance of Informal Seed System. However, most small farmers still rely on the Informal Seed System operating in resource-scarce areas, where complex environmental stresses challenge agricultural production. The Informal Seed System needs to strengthen for sustainable growth of the agrarian economy and conservation of biodiversity. Hence, the present review paper focuses on the status of formal and informal seed system in developed and developing nations, the positive side of informal seed system in the sustainable development of the agrarian economy, and the suggestive measures and methodologies to strengthen and improve the informal seed system to enhance its efficacy. This article addresses the character and importance of the farmers' seed systems and focuses principally on these

systems in developing countries. The farmers' system is described as an integrated system that functions parallel to the formal system. It is pointed out that the informal and formal systems are poorly connected, while their complementarity indicates that a better integration offers opportunities to improve seed system functioning for all stakeholders. This paper presents the importance of the Informal seed system and the prevailing informal seed system in developed and developing countries. We indicate ways to integrate further the formal and farmers' systems at various points in the seed chain/seed cycles and propose including such strategies in national seed policies.

The difference between the Formal and the Informal Seed System

In developing countries, the informal seed systems remain the dominant seed source for smallholder farmers. Such systems are termed "informal" because they are farmer organized and managed, flexible and dynamic, indigenous to a community or set of communities, local or regional in scope and scale, and typically undocumented. The informal seed system comprises several components such as farmer self-saved seed of indigenous annual and perennial field and vegetable crops, informal seed markets, seed networks, and 'germplasm gatekeepers' informal seed storage mechanisms and conservation of knowledge-based surrounding the local system. The informal seed system contrasts with the formal seed system, which involves governmental, institutional, or private control of the whole world of seed activities, including institutional controlled breeding, multiplication, processing, and storage. Such formal systems are typically vertically organized with specific structures in place for producing and distributing seeds and operate on generally strict and similar principles across the globe. These formal systems are the source of modern varieties and certified seeds usually developed through modern breeding (Anonymous 2019).

The importance of Informal seed system: Economic and Ecological sphere

The landscape in many parts of rural India is dominated by resource-poor smallholders, who operate complex, biodiverse farming systems. Informal Seed Systems central to such farming systems are critical to ensuring 21st-century global food security challenges for several interconnected reasons. First, seed sourced from informal systems by resource-poor smallholders in developing countries such as those in southeast Asia is estimated to account for 75to 90% of all food crops cultivated (Almekinders and Louette, 2002). Although some farmers may purchase seeds and access the formal seed system for some commonly cultivated food crops such as rice, the informal seed system is the primary and often sole source of most foods in these smallholder communities.

Secondly, Informal Seed Systems are critical for producing diverse foods to ensure dietary diversity in smallholder communities. Many crop species integral to the informal seed system provide useful nutrients to the communities where they are grown and consumed. In particular, informal seed systems are often the sole source of Neglected and Underutilized Species (NUS), which is critical for providing the vast majority of essential nutrients to smallholder communities. There is a significant potential to extend the nutritional benefits of neglected and underutilized species to regional and global levels to solve the growing problems of hidden hunger and increasing homogenization of the global food base.

Thirdly, informal seed systems are central to biodiversity conservation in smallholder production systems. The informal seed system is critical in maintaining biodiverseagroecology, as it is the main source of diverse germplasm. Furthermore, informal seed systems broaden the genetic base of production with multiple crop species and varieties adapted to specific production systems and microclimates. Smallholder communities can reduce risk in their agricultural systems by preserving in-situ locally adapted varieties saved through the informal seed system and cultivated in biodiverseagroecology (Thrupp 2000). Risks may involve ongoing environmental pressures facing smallholders daily, including pest and disease pressure, low soil fertility, and severe weather conditions. The locally adapted germplasm also provides communities with greater resilience in the face of significant events, including climate change, natural disasters, and political instability.

The strengthening of informal seed systems that revolve around a broad genetic base thus provides an alternative paradigm to increasing corporate control and monopolization of the global formal seed system, resulting in an increasingly rapid reduction in global seed bio-diversity (Osman and Chable, 2009). Finally, the rich diversity of indigenous germplasm in informal seed systems represents a valuable resource for developing and improving crop species locally, regionally, and globally.

Informal Seed System in Developing Countries: An African Perspective

The majority of farmers in developing countries mainly get their seeds from the informal channels which include farm saved seeds, seed exchanges among farmers and/or local grain/seed market. These channels contribute about 80-100% of seed supply depending on the crop and country. Despite the importance of these systems unlike the formal, informal sector systems are rarely supported by governments. Subsequently, its improvement has been limited or non-existent. Therefore, this harms agricultural productivity, farmers' income, and more particularly to the poor and marginalized farmers (Louwaars and Simon De Boef, 2012). It has been proved that once well supported and linked to sources of improved varieties, the informal seed sector can be a reliable and efficient way to access improved varieties of crops whose seeds attract a very limited interest of commercial seed sector. Therefore, an integrated seed system plays a crucial role in improving the informal seed supply towards the standard seed or to some cases formal seed supply systems. Informal seed supply systems focus on farmer management of local varieties which have been selected over time and produced under local circumstances. The system covers methods of local seed selection, production and diffusion. The systems are sometimes described as traditional and informal, operating mainly at the local level through exchange mechanisms and involving limited quantities per transaction. In addition, the varieties will have special attributes, *e.g.* taste and nutrition that give varieties added value within the community.

Governments will require clear strategies to encourage the improvement of the informal seed sector towards quality seed supply to gain from its benefits and potential. There are organizations at the International level that handle various issues affecting the World Seed Industry, especially the formal seed sectors. The Organization for Economic Cooperation and Development (OECD) gives regulatory guidelines on field certification standards; while the International Seed Testing Association (ISTA) provides rules for seed testing. Seed trade industry issues are articulated by the International Seed Federation (ISF) which encompasses

both public and private industry representatives of breeders and seed companies. Even with these organizations setting standards for the formalized seed supply system, the challenge will be on the IPR for Genetically Modified Organisms (GMO's) on some protected plant varieties. Secondly, there are no rules for the informal seed supply systems which appear neglected and yet it provides most of the seed nationally in developing countries.

Status of Informal Seed System in Developed Countries: An European Perspective

The market for seeds (production, sale, and exchange) is a much closer in Europe. Quality and The market for seeds (production, sale, and exchange) is a much closer in Europe. Quality and intellectual property standards make them into commercially standardized products. The legal and commercial room for agricultural biodiversity based on the varieties capable of evolving and adapting to their environment is increasingly limited. The dependence of farmers on seed industries is becoming increasingly marked. Nevertheless, in Europe, the proportion of seeds produced on the farm is not negligible. The seed industry constitutes a gap to fill, consisting of both farm seeds (protected varieties reproduced on the farm) and illegal seeds. Moreover, the common agricultural policy has accentuated the 'modernization' in European farming systems, with aid in research in agronomy and laws on seeds that have helped the farmers start and run the business of seed industries. Farmers in informal seed system see their limits as Technical, with DUS (Distinctness, Uniformity, Stability) characteristics according to the UPOV system that is incompatible with the ecological qualities required for their kind of farming; for the species concerned, particularly the major crops, the DUS requirement is supplemented by an assessment of the Value of Cultivation and Use (VCU) that guides genetic progress in a single direction, most often defined in terms of yield in intensive agriculture, or criteria of industrial quality: Political and legal, raising questions of how to design the regulatory space so that the farmers can regain their ancestral activity of producing their seeds and especially some sort of intellectual property over the varieties. In Europe, farmer organizations have emerged to offer an alternative for the future of informal seed systems: in France (the RéseauSemencesPaysannes – RSP), Spain (the Red de Semillas - RdS), and Italy (the Rete Semi Rurali). Their characteristics and their organizations display some common features:

- They bring together different civil society sectors concerned about cultivated biodiversity (associations, farming unions, institutions, etc.)
- They display rapid expansion measured by the number of member associations and campaigns (partnership research projects, biodiversity fairs, publications, training, etc.).
- They can communicate with the public widely and share their concerns.
- Their work at a national level is accompanied by a growing awareness of the need to extend the common task to European and international levels. They accordingly also belong to other civil society networks. They differ from professional farmers' organizations in employing people other than farmers themselves and bringing together all citizens who feel concerned about seeds in choosing their food, clothing materials, safeguarding ecosystems and agricultural landscapes, etc.

Seed Laws and Informal Seed Systems in South America: A Brazilian Perspective

In Brazil, the legal provision in the new Seed Law of 2003 allows the inclusion of seeds of local varieties in funding programs and public programs for the distribution or exchange of

seeds which is a major improvement in Seed Law (1977). Previously, the Seed Law treated the seed of local varieties as mere grains, making it harder for policies to support civil society organizations (CSOs) that aimed to partner with farmers in the recovery, improvement, and reintroduction of the informally produced seed of local varieties. The Seeds of Passion network in Paraíba, in Brazil, has produced seeds and grain for the institutional market because of such a policy change. Consequently, the legal acknowledgment of local varieties and informal seed systems allows policies to support several such initiatives, thereby creating many opportunities for income generation for small-scale farmers in harmony with the production and seed systems without converting to 'formal' industrial agriculture.

Selecting, storing, and exchanging seeds freely is essential for community biodiversity management. Seed laws and the relatively small amount of legal space devoted to informal systems make it difficult to adopt or promote models of agricultural development based on small-scale farming. Policies ought to promote a broad diversification of legal frameworks dealing with the innovations and development of the informal seed systems, development, and use of local varieties. Policies should devote more legal and institutional space to informal systems. Instead of arbitrarily imposing a single system (the formal system), policies ought to support a structure that could facilitate the coexistence of or promote pluralism in the various seed systems.

Approaches to strengthen Informal Seed Systems for ensuring seed and food security at the community level

To strengthen the informal seed systems, a community-oriented participatory approach must follow objectives and methodologies to enhance seed and food security. The following procedure should be adopted to materialize the functionalities of Informal seed system.

1. Understanding and Characterizing Informal Seed Systems

There is a need to conduct a variety of participatory activities to facilitate understanding of informal seed systems by researchers and households in the targeted regions. The first of these activities is to focus on semi structured households and conduct individual interviews in the identified regions. Sampling frameworks will be based on wealth stratification of each community to ensure that sampled households span the range of socioeconomic strata. Interviews schedule should be prepared to permit observation of actual seed saving and storage practices. Interviews should cover topics such as novel and annual seed acquisition, seed trade pathways, seed selection and saving practices.

2. Identifying species of potential commercialization

Participants involved in understanding and characterizing the informal seed system in their communities are invited to participate in a follow up activity to identify a list of important yet often still underutilized indigenous species. Participants are also asked to identify whether species are important or less important to their seed systems regarding household diet or as a potentially marketable crop. The activity is conducted to uncover which species has the greatest untapped potential for future crop improvement and commercialization for the target communities.

3. Characterization of Cropping Patterns and Cropping Systems

In these objectives cropping systems, cropping patterns, the tradition of mono-cropping and multiple cropping systems, sowing and harvesting times, crop productivity, profitable crops that are prevalent in the area, prospects of increasing crop production, nature of soil, its types and soil related problems needs to be evaluated and assessed.

4. Capacity Building of Community Field Technology Incubators and Pilot Farmer on Maintenance Breeding and Quality Seed Production Technology

Maintaining these landraces by strengthening informal seed systems involving small-scale farmers is the only way to conserve these landraces and traditional farmers' varieties. Contrary to the formal seed system, the informal seed system lacks technical and financial support from government academic research and corporate institutes. This is the reason why the Informal seed system operating at present is highly inefficient in terms of crop yield. The informal seed sector has to be strengthened to deliver the types of products needed to catalyze smallholder advances: to encourage increased production; nutritional gains, and foster farming system resilience. Strengthening the formal and informal seed system will be achieved by building farmers and seed personnel on quality seed production aspect through maintenance breeding, quality seed production technology, post harvest handling, seed storage facilities, and seed quality testing. Following methodologies can be adopted in different countries for capacity building of master trainers and pilot farmers.

- Based on the available information and secondary data, five villages in each district can be selected as a pilot village. From each pilot village, one field technology incubator shall be trained and these technology incubators will provide and manage the services for establishment and development of Informal Seed System of farmer's varieties and landraces under the supervision of researchers or a scientist at the university technology incubation centre.

- Field technology will be thus incubators trained on different aspects of improved seed production technology, community seed banking, seed health, cleaning, inventory maintenance, post-harvest handling, germination and vigour trials, storage and grow out for multiplication.

- In each village, clusters of 20 farmers will be formed and guided by the community field technology incubators from their group involved in establishing a sustainable seed production and delivery system at village level that will facilitate the spread of farmer referred traditional crop varieties in targeted villages and nearby areas.

5. Address technology barriers to seed analysis

The integrity and quality of seed produced by trained farmers need analysis to ensure the availability of quality of seed. For this, there is a need to establish one germination chamber at the community level for in-situ experimentation involving seed viability (germination and vigour). There is a need to establish one seed bank at a community level made out of locally available and low cost materials involving local non-governmental organizations. Field technology incubator should be trained regarding the seed quality testing technology and stimulate interest in simple research methodologies within the communities. Technology incubators will conduct Participatory Rural Appraisal (PRA) through local institutions, SHG (self help groups)/farmers associations/groups to establish Informal Seed System of farmer's

varieties and impart training regarding technological know-how of quality seed production and simple research methodologies of seed quality testing in each of the selected pilot sites of each district.

6. Integrated approaches in seed production and diffusion

A number of methods to introduce genetic material into local seed systems have been used. The organization of various demonstrations and seed fairs, school and NGO activities, distribution *via* the local country food stores (Sperling et al 1993b), all aim to feed cultivars into the local seed system and stimulate seed exchange between farmers. Knowledge of traditional networks, identification of key farmers, institutions and areas, geographical and ethnological barriers, are likely to increase the effectiveness of such programmes. The seed fair events create opportunities for farmers to learn about seed saving by field technology incubators, local institutions, SHG/farmers associations/groups, and sharing knowledge and seeds the majority of which were unavailable through the formal seed system. This creates awareness among farmers regarding the knowledge of different seed species, germplasm, locally available landraces and improved varieties (Almekinders et al 1994).

In order to increase the availability of informal seed system, germplasm and to extend the reach of this germplasm into new communities there is a need to encourage participants in seed fair, focus groups, NGOs, to donate a small portion of their available germplasm for conservation at the community level or seed banks managed by local NGOs which operate as a germplasm repository and accessions of locally important species with the goals of increasing the availability of appropriate seeds of selected regionally important crops among developmental workers and communities encouraging regional seed saving and sharing. Directed advice on local seed production technology can greatly improve the impact of introduced varieties and it can assist farmers in maintaining and improving their local seed and varieties. Activities in Nepal and in Latin America demonstrate that technical assistance to farmers in production of good quality seed and marketing of seed can result in successful small scale enterprises that can be very instrumental in regional seed supply and in the diffusion of new varieties.

7. Integrated Approaches in Breeding

Many researchers have described methods of farmer participation in plant breeding. These methods aim at generating genetic material that better suits the small farmer and his production environment. They concentrate on obtaining information on selection criteria directly from farmers and screening germplasm in farmers' fields in the final stages of selection. Sperling et al (1993) in Rwanda developed a further-reaching strategy. Women bean farmers, whom local seed specialists also acknowledged were involved in the selection process in an early stage. They could select from a wide range of germplasm on station for their own experimentation. On-farm verification of the introduction in pure stand and in local variety mixtures showed that farmers' own selections were more successful than the selections made by breeders. Additional to these formal breeding strategies are the assistance to farmers in improving their local germplasm by selecting and introducing resistance into landraces, cleaning and distributing seed from local cultivars.

8. Purification and multiplication of the seed of Farmers Varieties and Landraces and establishment of Informal seed production and delivery system

After evaluation seed is purified and variety is maintained at the Community level through community level field technology incubator under the guidance and monitoring of scientists and academia**.** Verification of produce for sowing purpose and seed quality, including seed germination, emergence, viability, vigor and health etc. is maintained at a community level. These seeds will be provided to the identified and trained farmers of the regions for multiplication. Safe and appropriate seed storage practices suitable for village conditions need 5to be developed. Publish seed production manuals in local languages for use by farmers. Promoting integrated seed production system(s) and village seed enterprises to ensure timely availability of good quality seed of farmer's varieties at an affordable price in required quantities. At the same time, seed system(s) will be replicated in adjoining and other potential villages also. Linkages will be established with local village Panchayat to upscale seed production and promote local seed enterprises.

Biodiversity conservation program at Jawaharlal Nehru KrishiVishwaVidyalaya, an Agricultural University situated at Central India with the motive of conserving the biodiversity of the state

Sustainable development is the key to poverty alleviation as human rights and sustainable human development are interdependent. With them, a holistic approach of political, economic, social, cultural and environmental development is achieved. In these initiatives, University has established Plant Variety Protection Cell in 2016 with an aim to Conserve Farmers Varietiesand provides local communities to retain control over their genetic resources through farmer's rights protection act under PPV & FR Act 2001. In these directions, University had explored 32 districts and collected farmer's varieties of 42 crops out of which seven are from cereals, 16 from pulses and oilseeds, 8 vegetable crops and 14 other crops and in total 1535 farmer's varieties/ land races have been collected. The lines collected have been registered with PPV & FRA, New Delhi, India for protection, and has got accession numbers for registering the varieties in the name of farmers to ensure farmers' rights. To achieve the goal of sustainable development of tribal areas through ensuring farmers rights over their varieties, the team of scientists has extensively surveyed the tribal districts of Madhya Pradesh, India where the university is located to explore the rich biodiversity of these areas namely Seoni, Mandla, Dindori, Umaria, Balaghat, Anuppur, Sidhi, Rewa and Shahdoletc Exploring and collecting 527 landraces/ farmers varieties of rice and the ethno botanical importance, traditional knowledge associated with these varieties has been done. To conserve these large-scale Farmers Varieties, financial supports are needed from the State government to establish one Long term germplasm conservation infrastructure. We are also in a process of preparting a database to document all the traditional knowledge and indigenous location, specific package of practices associated with cultivation of respective farmer's varieties of rice, but financial assistance from state funds has been required for creating the Traditional Knowledge Digital Library. Such digital database would enable patent offices worldwide to search and examine any prevalent use and thereby prevent grant of such patents to protect the theft of Traditional knowledge of tribal farmers. Process of preparing DNA profile database of unique farmer's varieties as it is essentially required for varietal protection. The problem of seed purity is there in these farmer's varieties which deteriorates the seed quality and

reduce yield and downgrade prices to be fetched from market. Therefore, a Farmers Varieties Informal Seed System in specific areas of its adaptation, where it is grown from long centuries ago through farmer's participatory mode to get full expression of its aroma and other peculiar qualitative trait. These varieties should be cultivated in an organic mode through farmer's participatory mode in cluster approach; this will help to develop the market value chain system.

Policy issues

- Uniform seed system guidelines for quality control through farmer's participatory mode should be formulated for farmers/local landraces.
- Seed systems for individual varieties should only be established in the geographical areas of their origin and should be protected under Geographical Indication Tag/ GI.
- Successful seed systems already exist in the European countries for farmers/local landraces varieties.
- Financial support should be made available.
- A policy should be formed in which only the farmers of the Geographical Indication area of the local variety is allowed for seed production, commercial seed production, marketing, etc.

Future prospects

Farmers' produced, selected and stored seed is still the predominant source of seed in the world which is the case in developing countries, but also in European countries, farmers' own saved seed is widely used. The methodology described in this review paper strengthens the informal seed system to ensure food security in both a comprehensive and effective way. All the activities described, either directly or potentially, strengthen all four pillars of food security. First and probably most effectively, food availability will increase in each community through activities that sought to expand the reach of germplasm into new households and communities. Activities undertaken to understand and characterize the informal seed system will increase local awareness and knowledge of foods (many underutilized) available to communities and affirm the value of their diverse germplasm resource base to provide enough food year-round. Hands-on training and *in-situ* experimentation will increase local knowledge of securing sufficient, high-quality germplasm for the subsequent growing season, thus enhancing the available food sources for future years. Seed fairs will improve food availability by promoting seed and knowledge exchange among diverse households, thereby increasing available food options to cultivate at the household level. Regional seed banking will make possible effective storage, evaluation and future dissemination of a wide range of available food sources for local communities. Secondly, access to the food will reduce the intra and inter-community barriers to seed access. Intercommunity barriers will be broken down through seed fair events, which serve to develop and enhance networks and market opportunities among diverse ethnic and socio-economic groups within a geographic area for increased access to diverse crop species and varieties. Thirdly, utilization of food is potentially improved by identifying multiple species that are highlighted as key crops yet commonly or rarely cultivated, served to strengthen the knowledge base of communities on their agro-biodiverse system and the need to continue to conserve these critically important species. The final pillar of food security that increases food systems' stability

is also potentially enhanced through an integrated approach in breeding through which material those better suits the small farmer and his production environment, resilience to climate change can be generated than monoculture system. The strategy adopted also leads to the capacity building and skill development of small and marginal farmers leading to the development of society in an open way irrespective of caste, creed, gender and religion. Entrepreneurship development in the seed sector will be realized by developing village-level seed enterprises alleviating the problem of unemployment and poverty, ensuring economic security. The introduction of improved biofortified varieties of staple crops into and among the farming community of informal seed system will lead to ensure and improve the status of nutritional security in the nation.

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GEO SPATIAL MAPPING OF MILLET AREAS

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Introduction

Millets are considered to be the next super food or 'nutri-cereals' of the world because of their high nutritional content. They can be useful as a sustainable means for nutritional security. According to ICAR-Indian Institute of Millets Research, Hyderabad, Millets contain 7-12% protein, 2-5% fat, 65-75% carbohydrates and 15-20% dietary fibre. They are more nutritious compared to fine cereals. They contain higher protein, fat and fibre content; are gluten free and non-allergenic. They have low Glycemic Index (*GI, value used to measure how much specific foods increase blood sugar levels*) and are rich in bioactive compounds and essential amino acids. Because of low GI, they are goof for diabetic persons; are also rich in micronutrients like calcium, iron, zinc, iodine etc. and they are three to five times more nutritious than wheat and rice in terms of proteins, minerals and vitamins. Millets can help combat cardiovascular diseases, anaemia, calcium deficiency etc.

Millets are sustainable food source for combating hunger in a changing world climate. Millets secure sixth position in terms of world agricultural production of cereal grains and are still a staple food in many regions of the world. These are rich source of many vital nutrients and hence, promise an additional advantage for combating nutrient deficiencies in the third world countries. Millets are resistance to climatic stress, pest and diseases and they can be stored for long with ease.

India named "Covid, Conflict, and Climate" as the world's primary food security challenges. Cultivation and popularisation of millets are placed in the context of the larger imperative of 'de-risking the global economy'. The Government of India has taken multiple steps to enhance millet production. Production and consumption ecosystem of millets faces certain challenges that need to be overcome to further improve adoption and consumption of millets.

Spatial and Non Spatial Data

- Spatial data is a term used to describe any data related to or containing information about a specific location on the Earth's surface.
- Non-spatial data, on the other hand, is data that is independent of geographic location.

Geospatial data can help to make better decisions by leveraging the power of spatial relationships. Making sense of its differences helps to make even better decisions and expand knowledge of data too. Geospatial mapping of the areas under cultivation of millets is an important task to plan for increasing area under millets cultivation and monitoring for interventions for enhancing the production.

Geospatial data is used for

- Land use and land cover mapping using Reomte Sensing data
- Land use area computation in GIS
- Crop classification and crop mapping
- Crop condition assessment
- Crop yield Forecasting
- Crop diversification
- Soil mapping and suitability classification
- Soil fertility mapping
- Soil erosion
- Soil conservation
- Seasonal and permanent surface waterbody
- Monthly, seasonal and annual potential evapotranspiration
- Monthly, seasonal and annual rainfall and drought
- Groundwater potential zone
- WHS site suitability
- Prioritization of watershed
- Crop classification
- Decadal land use land cover change

Land suitability is a function of soil characteristics and crop requirement. It involves the evaluation and grouping of specific areas of land in terms of their suitability for defined agricultural use. Factors such as soil characteristics, climatic condition, topography (terrain), rainfall, erosion etc. Henceforth, matching the land characteristics with the crop requirements provides suitability index in the form of ranks which are fundamental for sustainable agricultural practices. Sani et al. (2021) focused on GIS techniques for land suitability assessment and subsequently determine physical-chemical-climatic risk (to improve millet yield) in millet production for sustainable farming. This paper presents the land suitability for millet production in Katsina State (Nigeria). It was stated that different land unit requires different level of input and land management to facilitate (improve) millet production in Katsina state for sustainable crop production.

Crop mapping and time series analysis of agronomic cycles are critical for monitoring land use and land management practices, and analysing the issues of agro-environmental impacts and climate change. Multi-temporal Landsat data can be used to analyse decadal changes in cropping patterns at field level, owing to its medium spatial resolution and historical availability. Traditional pixel-based classification was analysed in comparison with image object-based classification using advanced supervised machine-learning algorithms such as Support Vector Machine (SVM).

Comparative analysis clearly by Devdas et al. (2012) revealed that higher overall classification accuracy (95%) was observed in the object-based SVM compared with that of traditional pixel-based classification (89%) using maximum likelihood classifier (MLC). Object-based classification also resulted speckle-free images. Further, object-based SVM models were used to classify different crop types for summer and winter seasons. The influence

of different shape, textural and spectral variables, and their weights on crop-mapping accuracy, was also examined. Temporal change in the spectral characteristics, specifically through vegetation indices derived from multi- temporal Landsat data, was found to be the most critical information that affects the accuracy of classification. However, use of these variables was constrained by the data availability and cloud cover.

Conditions necessary for Millet Production

Millets are a group of small-seeded grasses (*Poaceae* or grass family), widely grown around the world as cereal crops or grains. They are used as both human food and animal fodder. Millets provide food security to millions of households and contribute to the economic efficiency of farming. Millets include three major (Sorghum (*Jowar*), Pearl (*Bajra*), Finger (*Ragi*)) and six minor crops (Barnyard (*Sanwa*), Proso (*Chenna/Barri*), Foxtail (*Kakum*), Kodo, Brown Top and Little (*Kutki/Shavan*)).

They require warm temperatures for germination and development and are sensitive to frost**.** For these reasons, they are normally planted from mid-June **to** mid-July period. Optimum soil *temperatures* for seed germination are between 20°C and 30°C. Millet are efficient users of water and grow well in areas of low moisture. They can grow in areas with annual rainfall range of ~30-50 cm. Millets are often grown as catch crops (a crop grown in the space between two main crops or at a time when no main crops are being grown). They are highly adaptable to a variety of soil conditions, from extremely poor to very fertile, and can handle a degree of alkalinity. Alluvial, loamy, and sandy soils with good drainage are the ideal soils for millet cultivation. They are also hardier and drought-resistant crops, which has to do with their short growing season (70-100 days, as against 120-150 days for paddy/wheat) and lower water requirement (350-500 mm versus 600-1,200 mm).

Millets have low water requirement and are drought resistant. They have short growing season and require less water *during*growth.Millets have the potential to help achieve the sustainable development goals (SDGs), mainly **SDG 2** (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 12 (Sustainable Consumption and Production), and SDG 13 (Climate Action).

Challenges in Millet Production

The Green Revolution has altered the cropping pattern to wheat-paddy cycle. The area under Millet cultivation *reduced* from 37 million hectares in pre-Green Revolution period to ~14 million hectares. The Millets Mission has led to the inclusion of grain in the public distribution system. Low crop productivity, the lack of public awareness about nutritional benefits of millets has led to limited adoption of millets**.** In addition, limited distribution and lack of market knowledge have resulted in sub-optimal reach, lower price realization and wastage. Millets require multiple processing for optimization of grain recovery and optimization of polishing to retain their nutrition value. Processing of millets face several hurdles owing to variation in size of various *millet* types and low shelf life of the processed millets. There are variations within the same small millet crop due to variation in varieties, cultivation practices, and microclimate across production regions. Lack of processing units makes it difficult to bring cultivated millets to consumption market.

Steps required to promote Millet Production

- To identify millet focus districts and area suitable for them.
- To identify varieties of millets, suited to different agro-ecological zones and characterise their suitability for their promotion.
- To provide incentives to farmers for quality seed production/distribution, field-level demonstrations, trainings, primary processing clusters and research support.
- To support millet entrepreneurs, primary processing machines for dehulling millets (removal of husk) and the formation of millet farmer collectives.
- To promote of programme providing millet producers' effective market and farmers participation as member shareholders in these entities.

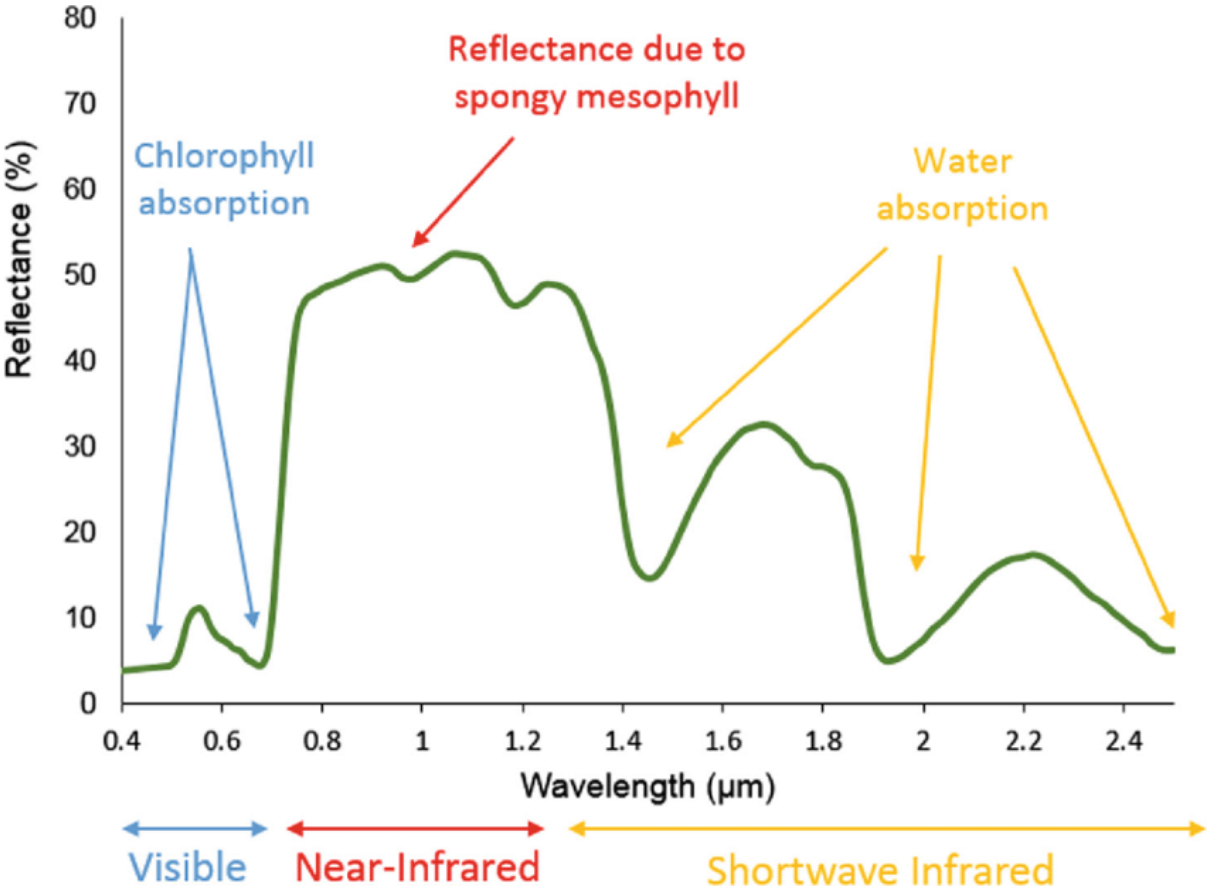
Geospatial mapping of the millet areas is necessary to enhance cultivation of millet on a broad scale which has the potential to assist farmers in safeguarding their livelihoods in the face of climate change. Mappings intensify the initiatives to promote millet production. Large area spatial and temporal monitoring of the cultivated areas shall be helpful to improve and scale up area under millet cultivation.

Morphological and Agronomical Characteristics of SitahiKutki:-

S. No	Character	State
1	Plant Height	70-77 cm (Average 75 cm)
2	Distinguishing morphological characters	
a.	No of productive Tillers-	02-03
b.	Panicle length	10-15 cm
c.	Maturity	75-80 Days
d.	Maturity group	Early to medium
e.	Reaction to major disease/ pest	Tolerant disease and pest
f.	Agronomic features	Resistance to lodging and drought condition
3	Quality of produce	
I.	Grain quality	
a.	Seed coat colour	Greyish to black shiny colour
b.	Seed size	Small size seed in compare with others hybrid varieties
c.	Seed weight (Test weight)	1.87 gm
2	Fodder quality	
a.	Fodder colour after maturity	Golden cream colour
b.	Fodder use	Palatable to cattle
c.	Fodder weight after maturity	Light weighted with very thin stalks
4	Reaction to stresses	Suitable for sole cropping in light textured (undulated and debilitated soil condition), organic soil, under rainfed condition
5	Special features	Very sweet taste

Morphological and Agronomical Characteristics of NagdamanKutki :-

S. No.	Character	State
1	Plant Height	131-135 cm (Comparatively tall)
2	Distinguishing morphological characters	
a.	No of productive Tillers-	03-04
b.	Panicle length	30-35 cm
c.	Maturity	114-116 days
d.	Maturity group	Medium to late
e.	Reaction to major disease/ pest	Tolerant to disease and pest
f.	Agronomic features	Resistance to lodging and drought condition
3	Quality of produce	
I.	Grain quality	
a.	Seed coat colour	Wheatish cream white colour
b.	Seed size	Small size seed in compare with others varieties
c.	Seed weight (Test weight)	1.61 gm
2	Fodder quality	
a.	Fodder colour after maturity	Cream Golden colour
b.	Fodder use	Palatable to cattle
c.	Fodder weight after maturity	Light weighted with very thin stalks
4	Reaction to stresses	Suitable for sole cropping in light textured, organic soil, under rainfed & Puddled condition.
5	Special features	Very sweet taste and suitable for liquid Daliya(Pej), Bhat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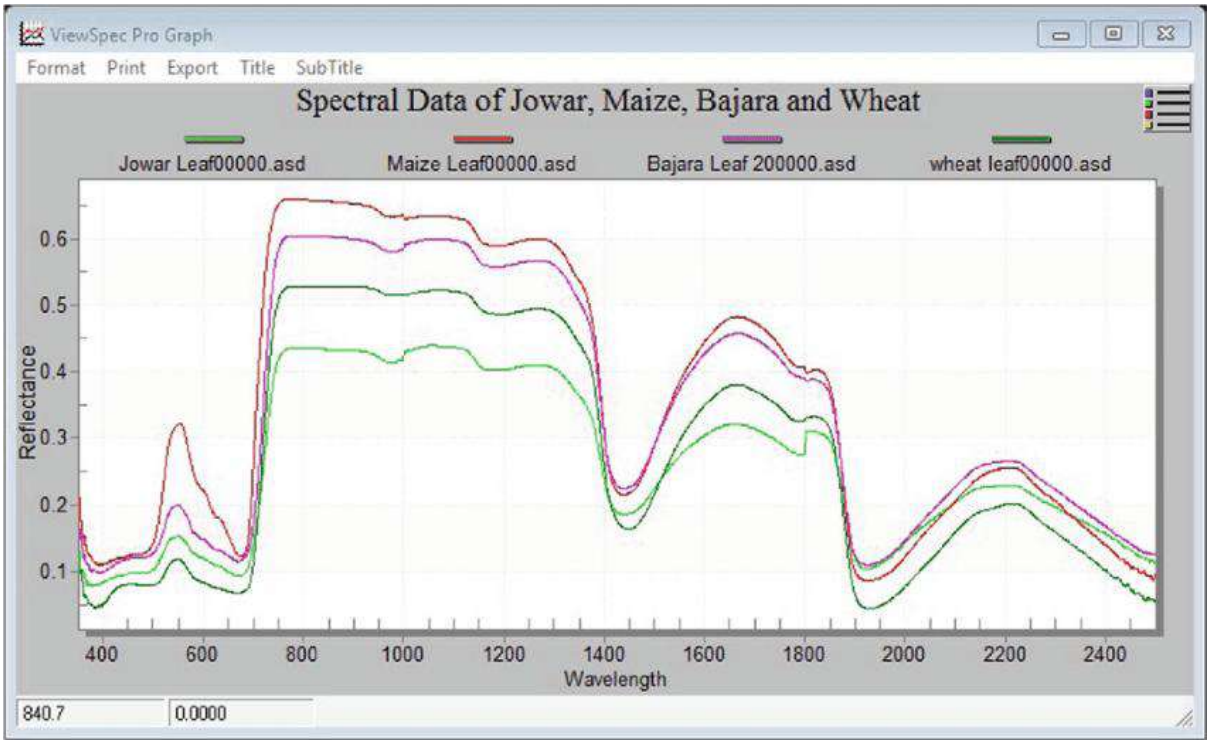
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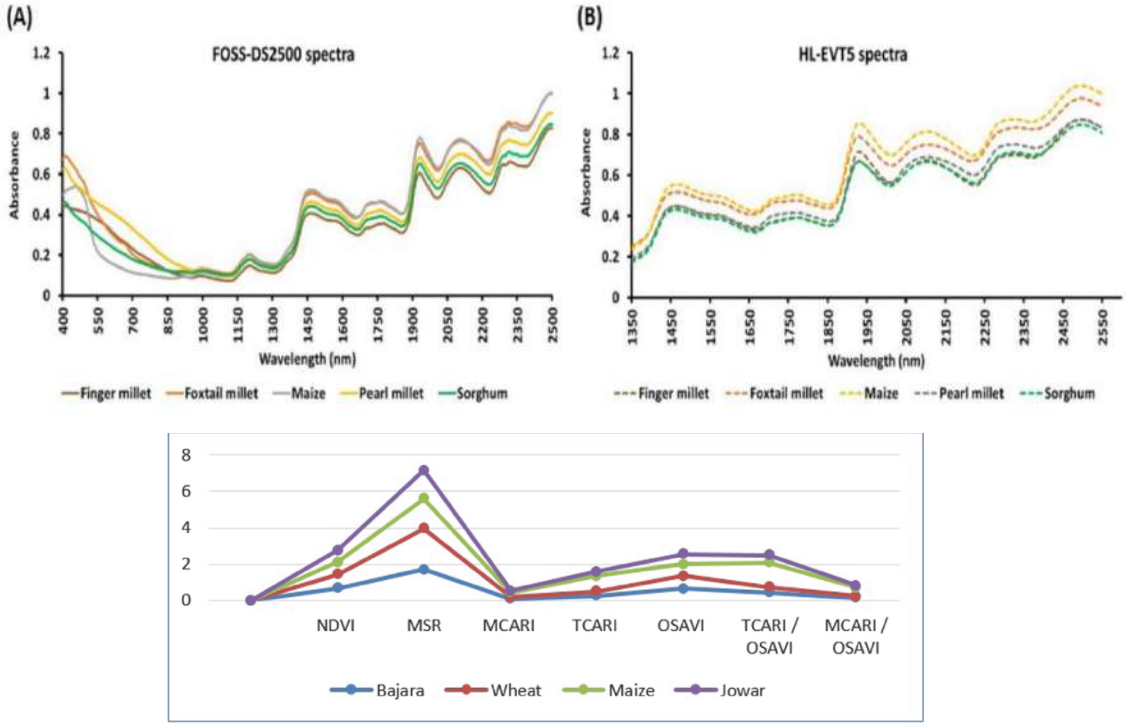

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LEAD PAPERS

THEME-VII

"POLICY ISSUES IN MILLETS PROMOTION"

ECONOMIC IMPORTANCE AND POLICY ISSUES OF MILLETS IN INDIA

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Millets are the group of small-seeded annual grasses that are grown as grain crops primarily on marginal land in dry areas and belong to the Poaceae family. Millets are the ancient food grains first domesticated for food and grown in 131 countries. Millets are the traditional food for 59 crore people in Asia and Africa.

Millets are the only crop that will address important issues in the future like food, feed, fuel, malnutrition, health, and Climate Change. Millets are adapted to a wide range of ecological conditions demanding less water and inputs and fit well even in the infertile soil.

There are nine types of Millets grown in India. The major millets are Sorghum, Pearl Millet and Finger Millet covering 95% of the total millet growing area in India and the rest 5% are Little Millet, Foxtail Millet, Barnyard Millet, Proso Millet, Kodo Millet, and Browntop Millet.

India has wide spread prevalence of malnutrition and hunger. Millets can solve this problem at very least cost. For example, Pearl Millet contains the highest iron content. It is about 4 to 8 mg per 100 gm of grain and has the ability to tackle anemia in India. It is also rich in Zinc and Folic acid and is recommended for pregnant women. Pearl Millet contains 2 times more protein than milk. India has the largest diabetic population in the world and it is pertinent to note that millets consumption has proven potential to tackle diabetes problem.

Climate change is the world's biggest market failure and millets are resilient to climate change as they are adapted to a wide range of temperatures, and moisture regimes, and demand less input to grow. They are hardy crops that have low carbon & water footprints. It can sustain drought and even 350-400 mm of rainfall is sufficient for millets. Millets grow faster, putting less stress on the environment. Thus, in the age of climate change millets can reduce risk of food insecurity.

India is the highest producer of millets in the globe and the 5th largest exporter of millets. Its exports are increasing exponentially as the demand for millets is increasing at a fast rate. Millets are addressing the need for fuel and feeds. It has the potential to produce biofuel.

As the demand for millets is increasing, it is creating more business opportunities for entrepreneurs. Millet Market size was over USD 9 billion in 2018 and will witness more than 4.5% CAGR during the forecast time-span(2018-2025) and the value projected is more than USD 12 billion.

Looking into the importance of millets following are the policy suggestions:

To promote coarse grains in the country, setting MSP for coarse grains like Sawa, KodoKutki, for which at present no minimum support price is fixed. By doing this, the production of these required coarse grains will be encouraged and reduced.

Coarse cereals should be compulsorily included in the mid-day meal and public distribution system. By doing this, arrangements can be made for compulsory procurement of these coarse grains.

Coarse grains absorb many times more greenhouse gases than they emit. Therefore, the government should deposit carbon credit money equal to the carbon absorbed by coarse grains to the farmers producing these grains in the farmers' account. This will be a big incentive which will increase the area of coarse grains manifold.

To develop storage and processing capacity for coarse grains in large producing areas of coarse grains. This will help in expanding and strengthening the value chain of coarse grains

- Providing zero rate GST to products made from coarse grains.
- To develop special seed systems for coarse cereals.
- Removal of all duties and restrictions imposed on the export of coarse grains.
- Developing a system to sell coarse grains in the local market. At present coarse grains of Madhya Pradesh are sold in neighboring states without doing business in the local market. For this reason, the system of business of coarse grains in Madhya Pradesh was not fully developed.
- Demonstration of recommended POPs among farmers for scientifically cultivation of coarse grains.
- Developing new varieties of millet which is responsive to modern agricultural inputs.

PRODUCTION, PROCESSING AND MARKETING OF MILLETS: CHALLENGES AND SOLUTIONS

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The ability to adapt to different climates while still providing high nutrition and improved health has sparked renewed interest in the country's traditional millets. Several organizations are pushing for changes that would improve millet farming and sales. The small-grained grass cereals known as "minor millets" play a significant role as both food and fodder in the world's semi-arid regions. Minor millets have traditionally been grown in the drylands of India, especially by low-income farmers and in some cases by tribal communities. However, this area is slowly shrinking. Concerns about food security, public health, and environmental stability have stoked resurgence in millet farming in the country. Despite the hardships of poor soil, low moisture, and scarce external inputs, these cereals have been sustaining millions of poor and marginal women and men farmers. They are valuable resources for dealing with the effects of climate change because of their resilience and high nutritional value. The millet sector has faced numerous challenges in terms of production, processing, value addition, marketing, and consumption, all of which have hampered the process of promoting millets as staple foods around the world. Some of the major challenges and policy intervention for millet promotion are as follows:

Challenges in millet production

1. Low millet productivity

Millets have lower productivity in the country than wheat, rice, and maize. This is due to their cultivation in marginal lands in rainfed farming, as well as the lack of adoption of improved cultivars. The yield gap in millets is largely due to farmers' cultivation technologies, which have plenty of room for improvement. Between 2009 and 2014, the country's average yield gap for rabi sorghum, kharif sorghum, bajra, ragi, and small millets was 58%, 151%, 62%, 183%, and 156%, respectively.

2. Pest/disease resistance

Though millets have few pests and diseases, shoot fly, stem borer, grain mould, downy mildew, and blast can cause significant losses in sorghum, pearl millet, and finger millet (blast). There are no productive cultivars with high resistance to these pests and diseases, so management is mostly agronomic and chemical.

3. Regional growth in unconventional locales

Increased production can be achieved by cultivating additional lands, particularly fallow and wastelands and non-traditional areas, which are more sustainable and do not compete with highly lucrative crops.

4. End-product-specific cultivars

For better end-product quality and scaling up the value addition by the large processors, geometrical and nutritional evaluation of several cultivars available in all the major millet growing regions and mapping them to the suitable end-use are essential.

5. Production of breeder seeds and seed hubs

In order to establish demand-driven production, it is imperative to identify various product-specific cultivars and establish seed hubs for breeding and producing such seeds. An essential intervention is the creation of seed hubs that can deliver high-quality seed at high production levels.

Challenges in millet processing

- Current machinery is inefficient, recovering only 70-80% of the grain, with the remainder being unhulled and broken grains.
- A single type of dehuller unit is not appropriate for all millets because their morphological characteristics differ primarily in size, shape, husk content, and nature.
- Husk separation and collection is time-consuming, resulting in spillage all over the working station and sometimes mixing with the final hulled output.
- Impeller speed has a significant impact on the de-hulling efficiency of millets. A provision for controlling machine speed is to be included.
- Due to the lack of gluten, gelatinization of starch through hydrothermal treatment, extrusion, and other methods is being used to diversify value addition, but making some products such as bread, buns, and so on with 100% millets remains a challenge.
- A lack of comprehensive data on the effect of different processing technologies on nutritional characteristics, as well as a framework of best processing technologies for increasing nutrient availability while decreasing anti-nutritional content.

Challenges in Marketing

- Millets export competitiveness and domestic and international price volatility cannot be assessed due to a lack of market intelligence. Market Intelligence, including consumer preferences, information on international market standards, emerging market segments, public domain regulations and trade policies, and more.
- There is no system in place to facilitate the establishment of connections between small businesses, large processors, government markets/programs, etc., which are essential for large-scale transactions and contract production.
- In addition, there were issues with low repeat purchases, low market awareness for ingredients and product formats, and a lack of a complete package of strategies for Branding, Positioning, USP, and Marketing in different consumer segments, countries, or regions.

Policy Interventions for promotion of millets

- It is necessary to expand millets cultivation across the nation, including in non-traditional areas such as UP, Punjab, and Haryana, in order to increase production for both domestic and international needs and to increase their yields.

- Providing incentives for millet cultivation to expand its acreage. Models of states such as Karnataka, where under "The Food of the Future" initiative farmers were given a 10,000/ha incentive to cultivate millets, can be replicated.
- Currently, the MSP only applies to major millets (Sorghum, Bajra, and Ragi); the MSP should be extended to minor millets.
- Biofortified millets can be made available to resource-poor farm households, as they reduce "Micronutrient" deficiency and can be a long-term solution for combating malnutrition.
- Incorporating the nutritional benefits of millets into school curricula, catering schools, and hotel management institutions, as well as public health care communications.
- Establishment of millet clusters, modernization of existing processing units, establishment of automated processed units, and establishment of export promotion forums are required for the uptake of millets exports.
- A shift in the paradigm of government policy from food security to nutritional security will have a greater impact on the future of millets. The Government of India's sub-missions for promoting millets and some state governments' piloting of millets missions would serve as scalable models.
- Convergence of various departments such as NITI Aayog, APEDA, MHRD, MOFPI, MSME, etc., with DAC&FW and ICAR, for promotion of minor millets.
- Speeding up the incubation of millet start-ups is a key forward link for meeting the needs of dynamic segments in both domestic and international markets. Increasing the number of millets-specific incubation centres, which will be done in partnership with state governments and with help from ICAR-IIMR, CFTRI, IIFPT, etc.
- Providing incentives for processing and exporting millet products to get big private companies like ITC, Britannia, Marico, Kellogg's, MTR, etc. to use millet in their products more aggressively.
- Getting small and medium-sized businesses to work better would be a key part of getting millet products into local markets and into government programmes.
- It's important to make "Millet-based Products" with the customer in mind. Companies should put a lot of effort into making sure there is enough demand.
- Millet-based products should be made and sold based on big trends in the food industry, such as convenience, snacking, and traditional foods.
- The health and well-being of customers should be taken into account, and the demand for superfoods and functional foods should be fed by millet-based products.
- Going against the general idea of "one product for all," companies should start making millet-based products based on what customers want.
- Creating a unique selling proposition (USP) for each type of millet by emphasising its nutritional benefits, as well as its superiority as a crop that is sustainable and resistant to climate change, and its importance for society.
- Systematically improving the millets value chain, from seeds and farming to tasty, healthy recipes and products, in order to increase India's share of international markets.

PROMOTIONAL POLICIES FOR MILLETS IN INDIA: PRELIMINARY REVIEW AND FUTURE CHALLENGES

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Introduction

Millets were considered ancient food grains and first plants domesticated for food. They are grown in more than 130 countries and are traditional food for 59 crore people in Asia and Africa. ICRISAT introduced the term Smart Food for millet, the food that is having the following unique characteristics:

- **Good for you**- highly nutritious (iron, zinc, calcium, proteins, fibre) and target some of the largest micronutrient deficiencies and needs.
- **Good for the planet**- low carbon and water footprint, serves as a mitigation and adaptation strategy for CC.
- **Good for the small farmer**- survive in high temperature, with very little water and external inputs.

Millets have superior nutritional values in comparison to highly consumed cereals such as rice, wheat and maize. These are rich in protein, minerals calcium, iron, and fibres and have a low glycemic index that help in fortifying essential nutrients for the healthy growth. Millets have often been called the coarse grains, however, because of their nutritional contributions they are now being referred to as 'nutria-millets or nutria-cereals'. Now it is brought in the category of "**Shri Anna"** (Union Budget 2023-24). Some of the hhighest nutritional content in millets (as compiled from Indian Food Composition, 2017 released by ICMR- National Institute of Nutrition, and Nutritive Value of Indian foods) are as follows:

- **Pearl Millets** – Fat (5.43 g), dietary fibre (11.49 g), Zn and Fe (2.76 & 6.42 mg),
- **Finger millets** – Ca (364 mg)
- **Kodo millet-** Folic acid (39.99 mg)
- **Proso millets-** Protein (12.5 g), Mg 153 (mg), Riboflavin (0.28 mg), niacin (4.5 mg)
- **Foxtail millets-** Carbohydrates (min 60.10 g), Thiamine (0.59 mg)

Millets are termed as the 'miracle grains' or 'crops of the future' as they can not only grow under harsh circumstances but are drought-resistant. These are dual-purpose crops, cultivated both for food and fodder, thus providing food and livelihood security to millions of households and contributing to the economic efficiency of farming specially in deprived areas of the country. These crops act as a good risk management strategy for resource-poor small marginal farmers (~80%). Millets are also unique due to their short growing season and contribute to mitigating climate change as it helps to reduce the atmospheric carbon pressure. The small millets does not attract pests and are not affected by storage if properly threshed and thus by default they are organically grown.

Global & National Production Scenario

India, Niger, China, Nigeria, Mali, Ethiopia, Senegal, and Burkina Faso accounts for more than 80 per cent share in production (2020). Global production of millets was 30.46 MMT and India's share was 12.49 MMT (2020). Indian alone account for 41 per cent of the millet production in the world (2020) and 80 per cent in Asia. India's average yield of millets (1239 kg/ha) is also higher than Global average of 1229 kg/ha. In India there are 16 millet, which are produced and exported, including Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Ragi) Minor Millets (Kangani), Proso Millet (Cheena), Kodo Millet (Kodo), Barnyard Millet (Sawa), Little Millet (Kutki), Two Pseudo Millets (BuckWheat/ Kuttu), Ameranthus (Chaulai) and Brown Top Millet. Pearl Millet (61%), Sorghum (27%), and Finger Millet (10%) are major millets accounting for 98 per cent of the total millet production in India. Millets are mainly grown in Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Uttar Pradesh, Gujarat and Haryana. The millet production in the country has increased from 17.26 million tons (2019-20) to 18.02 million tons (2020-21).Area of smaller millets has decreased from 2447 th.ha (1990-91) to 458 th.ha (2019-20). The reduction of 81 percent has occurred due to promotion of cultivation of major cereals, pulses, and cash crops on account of profitability and supportive policies.

International Year of Millets and G20:

The Government of India has realized the importance of millets in building Nutritional Security and made series of efforts such as gazetting millets from coarse cereals to Nutri-Cereals for production, consumption and trade on 10th April, 2018, and declaration of the National Year of Millets in 2018. Following India's petition to the Food and Agriculture Organisation, approved at the 160th session of the FAO Council in December 2018, the year 2023 is declared as the International Year of Millets.It was an important step in popularizing millets across the world. The millets export promotion programme also comes at the backdrop of the proposal of India. In the country, the ICAR-Indian Institute of Millets Research, Hyderabad led consortium has assumed the challenge of reviving millets production and has piloted several value chain interventions. Currently, there are 500+ agri-start-ups promoted under RKVY RAFTAAR RABIs and by other Incubation Centers across the country, and only a few big giant processors such as ITC, Britannia, Kellogg's, Marico, MTR Foods, 24 Mantra, etc. involved in the value chain.India is poised to play a key role in expanding millets' value chain at the domestic as well as global level. Year 2023 is in full swing to celebrate as the International Year of Millets by promoting Indian millets, recipes, and value added products at the global level. The campaign aims at promoting the health benefits of millets and their suitability under the changing climatic conditions globally. By doing so, it is expected that the demand for millets will grow exponentially in many countries.India gearing up with a host of activities to bring millets on the global food map, recently Prime Minister ShriNarendraModi urged farmers to adopt these nutritious grains as their preferred choice of crops and get benefit from it. He also highlighted its health benefits and flagged millets' role in fighting malnutritio. On the health benefits of millets, the PM said millets contain plenty of protein, fibre and minerals. Along with reducing obesity, they also reduce the risk of diabetes, hypertension and heart related diseases. Millets are also very beneficial in fighting malnutrition, since they are packed with energy as well as protein.India is the largest producer of millets in the world. Hence the responsibility of making

this initiative a success also rests on the shoulders of Indians," PM Shri NarendraModi said during his radio broadcast, 'Mann Ki Baat' broadcasted on 29th January 2023 in 97th edition.

India is currently is working in a double leadership mode-one with its G20 Presidency and the other with its mission to elevate Millets as the crops of the future.This timely acknowledgement accompanied with right actions (Getting Millets to become the king crop of 2023) can really reverse the whole global food order towards healthy, fibrous, and nutritious food intake. Also, when the entire world is slowly accepting veganism, protein-based diet and other health-friendly dietary changes, promotion and popularity of millets can bring a lot of business for millet-producing countries which are poor.The Millet year will result in more and massive production of the crop leading to unprecedented export figures, which can bring real changes and support economies of such countries by promising good growth for small farmers and eager entrepreneurs in these regions.India also seems ready to act on its millet leadership with full zeal with Millet festivals and events during G-20 presidency now being held already in different parts of the country bringing in participation of people from both within and outside the country and brought millets into diet in G20 meetings. The world is looking forward to know and adapt to millets, especially when it is so rich in dietary fiber, both soluble and insoluble. Emphasizing on the importance of these nutri-cereals, Prime Minister NarendraModi had said, "Millets have a glorious history of being among the earliest crops grown by humans. They have been an important food source in the past. But the need of the hour is to make them a food choice for the future.Another interesting fact about millets that may attract a lot of tummies around the world is that it lacks gluten and can be consumed by those affected by gluten-related disorders.

The Government has evolved the 'Seven Sutras' (themes) in the run-up to the IYOM, which is rolled out by the concerned Ministry/Departments,

1. Enhancement of Production / Productivity (DA&FW / DARE),
2. Nutrition & Health benefits (Ministry of Health / FSSAI),
3. Value Addition, Processing and Recipe Development (Ministries of Food Processing Industries & Tourism),
4. Entrepreneurship / Startup / Collective Development (Ministry of Commerce and DA&FW),
5. Awareness creation including Branding Labeling& Promotion (All Ministries),
6. International Outreach (Ministry of Commerce & Ministry of External Affairs) and
7. Policy Interventions for Mainstreaming (Dept of Food & Public Distribution and DA&FW).

Promotional policies

Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP) was launched in March, 2011. Rs.300 crores under RKVY for 'Nutri-cereals' (budget of 2011-12.) were allocated.The scheme has a unique feature to support improved technologies for production, post-harvest and awareness among the consumers and support for processing and awareness campaign. Creation of institutional infrastructure for value addition three commodity-wise national demonstrations cum training centres were set up at the Directorate of Sorghum Research (DSR), Hyderabad for sorghum; University of Agriculture Sciences, UAS, Bengaluru for finger millet and small millets and CCS Hisar Agriculture University, Hisar for pearl millet with the following objectives:

- Refinement of technology, retrofitting and their demonstration.
- Providing entrepreneurship development and training.
- Facilitate market linkages between processors and producers.

INSIMP is being continued as NFSM during 12th Five Year Plan (2012-17) with new targets of additional production of 3 million tons of coarse cereals. Millet based mid-day meal (MDM) was launched on pilot scale basis from 26th January, 2013 in Mahbubnagar (AP), Kolar (Karnataka) & Rural Pune (Maharashtra), Ariylaur&Perambalur districts (Tamil Nadu).As part of the Prime Minister's announcement of Aatmanirbhar Bharat Abhiyan, the Government, on 31st March, 2021, approved a Central Sector Scheme, namely "Production Linked Incentive (PLI) Scheme for Food Processing Industry" with an outlay of INR 10,900 crores to be implemented for a period of seven years from 2021-2022 to 2026-27.The primary objectives of this scheme include support to creation of global food manufacturing champions and support Indian brands of food products in the international markets. Specific food products segments having high growth potential are identified for providing support. These include ready to cook/ready to eat (RTC/ RTE) foods including millet based products.

In a major boost to production and exports of nutria-cereals like millet, Finance Minister Smt. NirmalaSitharaman, in her Union Budget (2022-23) speech, announced assistance for postharvest value addition and branding of millet products in the domestic as well as global markets. She proposed a policy push for branding of Indian millets, key ingredients in the breakfast cereals, biscuits and healthy snack segments. Mean while, the GOI has urged States and UTs to use millets under the PradhanMantriPoshan Shakti Nirman (PM POSHAN) while providing one hot cooked meal in Government and Government-aided schools during 2021-22 to 2025-26. She recently announced providing Rs 25 crore funds under the NABARD's rural infrastructure development to University of Agricultural Science (UAS), Raichur, Karnataka for establishment of incubation centre for processing and value addition for promotion of millets.

Export Promotion

India produces around 18 million tons of millets (2020-21). Exports of millets from India include mainly whole grain.India registered a growth of 8.02 per cent in the export of millets (FY 2021-22). Millets exported by India include Bajra, Ragi, Canary, Jawar, and Buckwheat. The top importers of millets along with their share in world import are Indonesia (8%), Belgium (7.36%), Germany (4.65), Mexico (4.1%), Italy (4.02%), United States of America (3.35%), United Kingdom (3.25%), Brazil (3.24%) and Netherlands (3.14%) in 2020. Top ten importers accounted for USD 221.7 million in 2020 out of the world import USD 466.3 million in same years. APEDA has prepared a comprehensive strategy to promote Indian millet exports across the globe. Facilitate participation of exporters, farmers and traders in 16 international trade expos and Buyer Seller Meets. APEDA has planned to showcase millets and its value-added product at various global platforms such as Gulfood2023, Foodex, Seoul Food & Hotel Show, Saudi Agro Food, Fine Food Show in Sydney (Australia), Belgium's Food & Beverages Show, Germany's BioFach and Anuga Food Fair, San Francisco's Winter Fancy Food Show among other places. According to the Department of Commerce, with the demand for Nutri-Cereals rising steadily globally, millet exports should increase exponentially in the coming years as Indian exporters find new markets abroad. Currently, India is the fifth largest exporter of millets in the world, according to 2020 data, with exports continuously increasing at around 3 per cent Compound

Annual Growth Rate (CAGR), in the last five years ending with 2020. In 2020-21, it is estimated that the millets market is set to grow from its current market value of more than USD 9 billion to over USD 12 billion by 2025. India exported millets of 26.97 USD million in 2019-20 against USD 28.5 million, including the top three destination countries i.e., Nepal (USD 6.09 million), UAE (USD 6.09 million), and Saudi Arabia (USD 3.84 million). The other top seven countries are Libya, Tunisia, Morocco, UK, Yemen, Omen and Algeria. These 10 countries together accounts for 80 per cent of India's exports.

ICAR-IIMR and APEDA have been organizing sensitization events to educate millet startups on value addition, emerging trends and potential export markets. Thus, a framework is in place to work on the refinement of the value chain for export markets, with the involvement of several other stakeholders such as ICRISAT, NIN, IIFPT, DFRL, CFTRI, Private companies, FPOs, etc. Ambassadors of Foreign missions in India of the targeted countries and potential importers would also be invited to showcase various millet-based products, including ready to eat millet products and facilitate B2B meetings. Major international retail supermarkets like Lulu group, Carrefour, Al Jazira, Al Maya, Walmart, etc. would also be roped in to establish millet corner for branding and promotion of millets. As per the government's robust strategy, Indian missions abroad would be roped in branding and publicity of Indian millets, identification of international chefs as well as potential buyers such as departmental stores, supermarkets and hypermarkets for organising B2B meetings and direct tie-ups.Centre has created the Nutri Cereals Export Promotion Forum to give impetus to the export of potential products, including millets, and to remove the bottlenecks in the supply chain of Nutri cereals. APEDA launched a variety of millet products for all age groups at affordable prices during AAHAR food fair, which is Asia's biggest B2B international food and hospitality fair. The APEDA has planned to organise millet promotional activities in South Africa, Dubai, Japan, South Korea, Indonesia, Saudi Arabia, Sydney, Belgium, Germany, UK and USA by facilitating participation of different stakeholders from India in some of the significant food shows, Buyer Seller Meets and road-shows.For promotion of Indian millets and its value-added products, the Indian government has developed 30 e-Catalogues on each of the targeted countries comprising information on various Indian millets and range of their value-added products available for export, list of active exporters, start-ups, FPOs and importer/retail chain/hyper markets, that to be circulated to the Indian Embassy abroad, importers, exporters, start-ups and stakeholders.An action plan for expanding exports of millet and millet products from 2021 to 2026 is being prepared by APEDA to enable all stakeholders to take the necessary steps in a time-bound manner to meet the aim.

State Specific Initiative

Andhra Pradesh Initiated millet board in 2020 under which they are promoting millet awareness and establishing millet processing units. Comprehensive Revival of Millets cultivation' by tribals in north Coastal Andhra and parts of Rayalaseema is an end-to-end program on Millets Revival in Andhra Pradesh, the program intends to develop tribal, and rain fed areas into MILLET-HUBS that can potentially supply millets to meet increasing demand and find its place in the grain economy. This project aims to increase productivity, household consumption, and value addition by making ragi biscuits, idli and dosa, marketing support, setting up of processing centers and establishing seed production centers. Keeping in view of the importance of iron, protein and energy rich nutrition to pregnant women, lactating mothers and

children below 6 years, certain changes were suggested to maintain uniformity and greater coverage of beneficiaries with recommended nutrition standards, focusing mainly addition of millet food items in Supplementary Nutrition Programme (SNP) like YSR SampoornaPoshanaYojana (YSR SampoornaYojana Plus for Tribal Sub Plans). In Andhra Pradesh under MDM, state is actively considering bringing in ragimudda and ragichikki in food habits.Chhattisgarh is planning to include Ragi in Ready to Eat/THR packets. Department of Women and Child Development is planning to procure ragi at a rate of Rs 45 per kg, nearly Rs 12 higher than MSP. Directorate of Agriculture, Chhattisgarh has proposed procurement of Kodo millet and Little millet.Karnataka organized international trade fair on millets, inclusion of millets under PDS under Anna BhagyaYojana scheme, launched SahajaSamrudha scheme for millets promotions. With 'superfood' and 'eat smart' strategies forming the main ingredients of the latest dietary mantras, Kerala State Agriculture Department is earmarking farm space in districts for growing nutrient-rich milletsunder Millet Village scheme . It is a special scheme to promote the cultivation of nutri-cereals such as millet, ragi, bajra and maize by setting up a millet village at Attappady. The project aimed at protecting seeds of traditional varieties of millets and ensures food security and livelihood for tribal.The Madhya Pradesh government is promoting kodo and kutki. An initiative has been taken to include millets in the food prepared for the patients in AIIMS Bhopal. Recently millets bases products have been served to the participants in the G-20 Agricultural Group Meeting at Indora. Madhya Pradesh received "Best Emerging State in Millet Promotion Award 2022". Odisha to become the first Indian state to include millets, pulses, vegetables in mid day meals and ration scheme. Odisha Millet Mission (OMM) started in 2017 and is currently implemented in 76 blocks covering 14 districts. OMM is mainly on three millets: foxtail millet, finger millet or ragi and barnyard millet. However, a state government official said on the condition of anonymity that it is mostly ragi (> 80 %), under the mission because of people's acceptance. OMM is a comprehensive program that focuses on farm to fork approach. It is a partnership between governments, farmers, CBOs, NCDS, WASSAN led civil society.Based on the baseline survey of 7000 OMM farmers done by NCDS, yields have doubled and income from millet has tripled. Under OMM, procurement of ragi and distribution has also been undertaken. Currently, ragiladoo is being included in ICDS in Keonjhar targeting 1.5 lakh children. Phase wise science-backed inclusion of millets in ICDS/MDM is being planned. OMM aims to revive millets on farms and plates with simultaneous focus on production, processing, consumption, marketing, and inclusion of millets in Government schemes. The major objectives of the Odisha Millets Mission (OMM) are increase household consumption, setting up decentralized processing units at block level, increasing productivity of millets crops through improved agronomic practices, conservation and promotion of local landraces, better marketing of millets through farmer producer organizations and inclusion of millets in ICDS, MDM and PDS.Odisha under Organic Millet Mission initiated custom hiring centre for millets, distributed ragiladdu through Integrated Child Development Scheme, and distributed millets through public distribution (PDS). Rajasthanestablished Centre of Excellence on Millets in Jaipur with around 100 millet processing plants announced in the recent budget by the state of Rajasthan. Tamil Nadu initiated Millet Mission scheme which consists of front-line demonstrations, providing mini kits to the farmers and organizing training to farmers.Telangana launched a mini mission on millets in 2018 for a period of five years in six districts.

Challenges: Millet sector has been facing numerous challenges pertaining to production, processing, value addition, marketing and consumption which have hindered the process of advocating millets as the staple foods throughout the world. Some of the important challenges are as follows:

1. **Weak Supply Chain:** Unlike rice and wheat, there has been dwindling development of the supply chain, especially as it relates to support for growers,traders, marketers, subsidiaries, and processors, FPOs/FPCs.
2. **Consumer Awareness:** Consumer awareness of the better nutritional value and other health benefits are inadequate or practically non-existent. Over the decades, consumer preferences have shifted to tastier and convenient foods either by demonstration effect of western culture or "indigenous misconception that millets are poor man's foods.
3. **Poor Yields:** Yields of 4–5 q/ha as compared to ~30 q/ha of rice, ~ 25 q/ha of wheat, and ~30 q/ha of maize are also drivers of the disparity in return.This is attributed to their cultivation in marginal lands in rainfed farming and non-adoption of improved cultivars. The yield gap in millets is largely a reflection of farmers' cultivation technologies that offer ample room for improvement. The country's average yield gap for rabi sorghum, kharif sorghum, bajra, ragi and small millets were 58, 151, 62, 183 and 156, per cent respectively.
4. **Inefficient Processing Facilities:** With a general 60–65 per cent recovery rate during processing, the "un-exploration" of by-products also contributes to the higher final selling price. One type of dehuller unit is not suitable for all the millets, as their morphological features differ mainly in size, shape and husk content and nature. Separation of husk and its collection is burdensome, which causes spillage all over the units and sometimes mixes with the final hulled output. Due to lack of gluten, gelatinization of starch through hydrothermal treatment, extrusion, etc., is being employed for the diversification of value addition but making some products like bread, buns, etc., with 100 per cent millets is still a challenge.
5. **Uncoordinated Policy:** After the Green Revolution, the policymakers in India have supported the production of rice and wheat in resource reach areas, contributing to the decline of acreage under millets.On the other hand availability of subsidized rice has not only led to decreased consumption of millets but has also affected the nutrition levels. This has further resulted in declining areas under cultivation, decreased interest in cultivation of the crop and loss of traditional varieties. Since the government provides rice at one rupee a kilo and growing millets is not anymore essential to fight hunger, people are further disinterested in growing these crops on account of low productivity.
6. **Restrictions of quantum of ragi procurements:** There is a restriction on the quantum of ragi to be procured under MSP to total estimated production potential. This is due to central government's set upper limit and lack of adequate financial allocation from the state government.This problem is specially face by producers of Odisa and Karnataka for ragi.
7. **Inadequate storage system**: Attention to storage of millets is inadequate. Government doesn't have adequate storage as the available grain stocks of rice-wheat are already overflowing and more than double the buffer stocking limits.

8. **Lack of state specific policy on MSP:** There is no established policy of state governments to provide MSP to additional crops which are not covered by the central government except in state like Maharashtra.
9. **Inefficient supply chain for seed:** Supply chain of millets seeds except per millets, sorghum and ragi is inefficient, and there is a need to work on ensuring their availability. Small millets seed system is mainly dominated by informal sector (.90%). Also, seed subsidy is available to farmers only on released or certified seeds. By taking a complete commercial approach for the cultivation of millets, the crop may slowly become a monoculture of a few varieties like the other cereal crops like wheat, rice and maize. This can lead to loss of crop diversity and *in situ* evolution with climate change. It would also put the crop at risk of being lost during any natural calamity, disease or pest incidence. Thus, strategies to maintain land races are required in parallel for development of new varieties.

To overcome these challenges, there is a need for concerted efforts towards mainstreaming millets by diversifying production technologies, building forward and backward linkages by promoting FPOs/FPCs, nurturing the start-up eco-system and bringing millets to the food plates at national and international level.

Opportunities: Millets are being increasingly recognised as climate-smart crops with enormous nutritional and health benefits. They are depicted as emblematic of India's "forgotten great culture and tradition". This has naturally led to a focus on millet farmers who have been struggling with stagnant yields and declining incomes. However, there is no conclusive number of millet farmers in the country, as only 11 per cent of the total sown area for food grains is under millets, which, in turn, account for just 6 per cent of foodgrain output. With increasing population and income and changing food habits towards healthy fooddemand for millets will increases. This has been rediscovering as nuti-food and therefore, the millets consumption as dietary food in coming years will increase. Moreover, many agri-start-ups and MSMEs are coming up with millets-based food products which are likely to attract more demand in coming year. Future possibilities in global markets are also increasing. Policy interventions such as inclusion of millets in RODTEP (Remission of Duties/Taxes on Export Products) scheme will aid in fueling the exports of millets. For targeting export markets, an advanced solution like Champion Millets to be implemented, a couple of millets will be selected and then positioned and branded with a clear proposition for a targeted countries. It is estimated that the millets market is set to grow from its current market value of more than USD 9 billion to over USD 12 billion by 2025.

Way forward: For promotion of millets as regular food major policy interventions are required such as:

1. FPOs\FPCs needs to be promoted for strengthening supply chain of millets in remote areas.
2. Bringing small millets under MSP will create a supportive environment that has long term dividends ranging from sustainable food and nutrition security to mitigate CC. To achieve a higher degree of crop diversification under the millet's family, it is imperative that the farmers be incentivized with MSP for all groups of millets in addition to ragi (finger millet), jowar (sorghum), and bajra (pearl millet). Introducing small millets in state-wise crop complex selection for coming block period and establishing facility for obtaining its cost of cultivation data will be helpful in deriving the MSP for minor millets.

3. Government should organize the procurement of millets with adequate procurement facility in millet cultivating districts with incentive prices.
4. Provide financial support to states, to offer minimum support price for millets that are not covered under central government scheme considering the variations and preference in cultivation of millets across different states.
5. Government should digitalize the food management system starting with demand, procurement from farmers to storage and distribution. This will improve area of millet cultivation specially small millets.
6. Including millets in contingent crop plan would encourage the farmers to cultivate all varieties of millets, which would increase the overall millet production, make different varieties of millets with exceptional nutritional value available in our markets and subsequently diets of people. This would also reduce input costs for the farmers and water-stress by shifting from water intensive crops to millets benefiting both the farmers as well as the environment.
7. Area expansion in non-traditional areas by bringing the fallow and waste lands under millets cultivation is another important factor in increasing the production, especially in non-traditional areas. These crops will be more sustainable without competing with the high remunerative crop.
8. There is a huge need for identifying various product-specific cultivars of millets and establishing the seed hubs for breeding and producing such seeds so as to establish demand-driven production.
9. Quality standards and their certification is still a major drawback for export of millet based product. Lack of knowledge about export policies and understanding about the markets in different countries is another constraint.
10. There should be more focus on the modification of current processing machines to ensure the conversion of millet seeds into flour. To sustain multi-cropping and intercropping, multi-processing units should be established at the same place.
11. There is a need to bridge the gaps in R&D related to shelf life, primary and secondary processing machines, nutritional evaluation, scaling up the successful millet value chain model developed by ICAR-IIMR, incentivizing millet cultivation and mainstreaming millets in public funded programmes, export promotional activities etc.
12. Millet hotspots like Mandla and Dindori districts in Madhya Pradesh, Malkangiri district in Odisha, the Garhwal district in Himlayas and Kolli hills in Tamil Nadu. These locations should be promoted for conservation of millet diversity and development of millet based agri-tourism.

Sum up: A well planned millets promotion ecosystem approach is needed for supply of quality seeds, input support, production management, social safety nets, women empowerment, processing infrastructures at hotspots, value chain development, market support, household consumption promotion, product development innovations, promotion through welfare schemes (Integrated Child Development Services, Mid-Day Meal and PDS), price and procurement support and other policy incentives for breaking the initial apathy and imbalance around millets and promoting as future global food.

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