ENVIS Newsletter

Himalayan Ecology

ISSN: 2277-9000 (Print)
ISSN: 2455-6823 (Online)

Vol. 20(1), 2023

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International Year of Millets

Echinochloa frumentacea

Setaria italica

Eleusine coracana

Millets rhizosphere: pathways of dealing stress to become climate smart crop

The world's arid and semiarid regions, especially in Africa and Southeast Asia, are vital zones for cereal production. Unfortunately, the majority of crops have experienced more than a 50% decrease in yield due to the abiotic stresses caused by climate change, which are the primary causes of crop loss worldwide. Millets are better able to withstand most abiotic pressures, including drought and high temperatures, but they still require strengthening to cope with the unprecedented consequences of climate change and related environmental challenges. This research aims to better understand how millets' rhizospheres cope with stress and how they can help crops adapt to a changing climate. One of the key characteristics of millets is their high nutritional value compared to other cereal crops (Rai et al. 2023). Millets are an excellent resource for the food industry as they contain essential nutrients and phytochemicals with health benefits for humans. However, multiple environmental stressors and impending climate change are limiting their output. The productivity of millet crops has been seriously threatened by stress caused by both heat and drought. For instance, pearl millet can lose up to 60% and 40% of their yields due to drought stress in the seedling stage and terminal drought during the reproductive stage, respectively. Fortunately, there are several ways to increase the ability of millets to withstand stress and produce more. This review paper highlights the effects of different stress on millets under a climate change scenario, as well as their innate mechanisms for increasing stress tolerance and yield. By understanding these mechanisms, we can help to ensure the sustainability of millet production and improve food security in regions that rely on this significant group of crops.

Climate stressors and Millets: Climate change is causing a variety of abiotic pressures that are impacting food crops in one way or another, which directly impacts the world's food supply. Drought stress, heat stress, floods or water logging stress, and lodging are the main impacts of climate change on millet crops.

Drought Stress: A study on wild millet (*Setaria glauca*), foxtail millet (*Setaria italica*), small millet (*Panicum sumatrense*), and proso millet (*Panicum miliaceum*) found that when subjected to dryness before to flowering, the yield was significantly reduced (Table, 2016). In areas prone to drought, plants use a variety of abiotic stress tolerance mechanisms Recently, a review of four key millet adaptation mechanisms to places suffering from drought was published (Tabel, 2016). These defense mechanisms include i) drought avoidance, which refers to a plant's capacity to maintain water balance under stress to prevent water deficiency in tissues, (ii) drought tolerance, which refers to a plant's capacity to produce biomass while withstanding reduced water potential, (iii) drought escape, which refers to a condition in which plants mature before experiencing drought stress, and (iv) drought recovery, which refers to a situation in which plants provide some yield while recovering from intermittent.

Heat Stress: Despite the fact that the majority of millet species are heat-tolerant, heat causes numerous physiological and biochemical changes. The most vulnerable biological functions to heat stress are photosynthesis and respiration, which has a significant impact on crop output. Several crops have already seen significant yield loss due to heat, and the annual increase in temperature brought on by climate change poses a threat to food

EIACP Centre on Himalayan Ecology

ENVIS Newsletter

A Quarterly Publication Vol. 20 (1), 2023

The "EIACP Centre on Himalayan Ecology" is housed at G.B. Pant National Institute of Himalayan Environment (GBP-NIHE), Kosi-Katarmal, Almora, Uttarakhand, which is an autonomous Institute of Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India, New Delhi, India.

The **"EIACP Centre on Himalayan Ecology"** collects, collates, compiles and builds quantitative and qualitative databases of information in the fields related to the Himalayan Ecology. The information is disseminated regulary via online as well as hardcopies to several valuable stakeholders and various users such as DICs, universities, institutions along with other EIACP Centres across India to support overall Environmental Information System in India.

Photo credit: Front (*Himanshu Joshi, Ravindra K. Joshi and https://www.feedipedia.org)*

Editor's Note

The Year 2023 has been declared as the 'International Year of the Millets' by the FAO of the United Nations.Since time immemorial, millets have been widely grown and used as major food and fodder in Indian includingthe Indian Himalayan Region (IHR).Millets are the group of small grained cereal crops and some of the important crops are Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Madua), Little Millet (Kutki), etc. There are various reasons behind promoting millets as future crops but the most important is they can grow in extreme weather conditions and also drought resistant. Most of the millets are native to India and that's why India is willing to position itself as a global hub for millets and also promoting millets at global level.

According to climate experts, millets can be a climate-smart option for farmers. Millets such as foxtail millet, proso millet, finger millet, and pearl millet are the most commonly grown crops even in shifting cultivation. They provide a variety of seasonal native foods for traditional uses including ceremonies, occasions, and festivitie. India produced 120 lakh tonnes of the total 304.8 lakh tonnes millets globally in 2022. The worldwide three countries namely India (40%), Niger (11%) and China (9%) are collectively produced more than 50% of the total millets. The international year of millets aims to contribute in the sustainable development goals of UN agenda 2030 by targeting SDG 2 (Zero Hunger), SDG 3 (Good health and well- being), SDG 8 (Decent work and economic growth), SDG 12 (Responsible consumption and production), SDG 13 (Climate action) and SDG 15 (Life on land).

The present volume [20 (1), 2023]of the EIACP Newsletter is in the series of its quarterly non-priced (print and electronic) publication and contains 13 articles related to climate smart crop, food security, millets and their nutraceuticals properties, millets diversity in Himalaya, heath benefits of millets etc. The views in this newsletter are the views of the concerned authors. Therefore, they do not necessarily reflect the views of the editors or EIACP Centre and the Institute. We look forward to come up with the policy interventions for the holistic and sustainable development of the Himalayan region. The comments/suggestions for further improvement of the EIACP Newsletter are welcome.

Er. Mahendra Singh Lodhi
EIACP, Coordinator

security. An increase in temperature of 3–4^{0}C has been associated with yield losses of up to 35%. Upregulation of the antioxidant system, transcription factors, heat-shock proteins, signalling molecules, ion transporters, and accumulation of osmoprotectants are some of the mechanisms of tolerance. As a consequence of normal cell metabolism, ROS can cause oxidative stress when its concentration is excessive. The majority of plants have ROS-fighting pathways as a defence mechanism against diverse abiotic stressors (Gupta *et al*., 2013) Water logging Stress: When soil pores are overfilled with water, a condition known as waterlogging, hazardous chemicals build up and gas diffusion is inhibited. As a result, photosynthesis, stomatal conductance, and roots are eventually impacted (Linkemer *et al*., 1998). Plants have a variety of defense mechanisms to deal with waterlogging stress, which is brought on by hypoxia (reduced oxygen level) or anoxia (Matsuura *et al*., 2016). Grain yield losses of about 18% in wild millet and 16% in proso millet were reported with waterlogging treatment that lasted from two weeks after planting through crop maturity (Linkemer *et al*., 1998). As a response to low oxygen levels, plants engage in anaerobic respiration, which has been observed in finger millet (Eleusine coracana) (Hossain and Uddin, 2011). In finger millet (Ni *et al*., 2018) and sorghum (Sorghum bicolor) (Kulkarn *et al*., 2014) adventitious roots have been seen to develop.

Millets rhizosphere for Enhancing Stress Resilience in Crops: IAA Synthesis: Several plant species that had IAA-synthesizing bacteria injected into them saw better root growth, the development of root hairs, and lateral roots which improved their ability to absorb nutrients and water and supported their ability to withstand osmotic stress Egamberdieva and Kucharova, 2009). The ability of microorganisms to produce hormones and their activity in promoting endogenous hormones both considerably improve resistance. Azospirillum brasilense produces nitric oxide (NO), which is involved in IAA ignaling and helps tomato plants (Solanum lycopersicum) grow adventitious roots (Molina-Favero *et al*., 2008).

Activity of ACC Deaminase-Synthesizing Rhizobacteria: Endogenous ethylene supports homoeostasis under stressful circumstances, which inhibits the growth of shoots and roots. When bacterial ACC deaminase reacts with aminocyclopropane-1-carboxylic acid (ACC), it causes the plant to receive energy and nitrogen (Etesami *et al*., 2020). ACC is a precursor for the biosynthesis of ethylene (Polko and Kieber, 2019). Moreover, the absence of ACC permits the bacteria to lessen their ethylene toxicity, which fosters development and lessens stress (Glick, 2005) Plant Growth-Promoting Rhizobacteria (PGPRs): PGPRs have been shown to improve abiotic stress tolerance and yield in a variety of crops. Economically significant crops like rice, soybeans, lettuce, tomatoes, maize, and wheat have all benefited from the usage of PGPRs to reduce abiotic stressors and increase production. Gibberellic acid (GA) and indole acetic acid are two crucial plant growth regulators that are biosynthesized by PGPRs, which is one way they help plants perform better (IAA). The production of other growth regulators including jasmonic acid and salicylic acid was also discovered to be triggered by PGPRs in plants (Jogaiah *et al*., 2018). The presence of PGPRs improves the stability of plant cell membranes by activating the antioxidant defence mechanism, increasing plants' tolerance to drought (Gusain *et al*., 2015). Almost all millet crops have built-in defenses against environmental stresses like heat, drought, lodging, and waterlogging, but these challenges continue to pose a threat to millet output as the effects of climate change. In this case millets rhizosphere plays a very essential role. A high-yielding, stress-tolerant variety of millets must be created in order to combat

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The wonders of super food millets

the impacts of pressures brought on by climate change and to increase millet output. Therefore Millets need more attention from researchers to improve global food security in the face of climate change, which is adversely affecting the productivity of staple crops.

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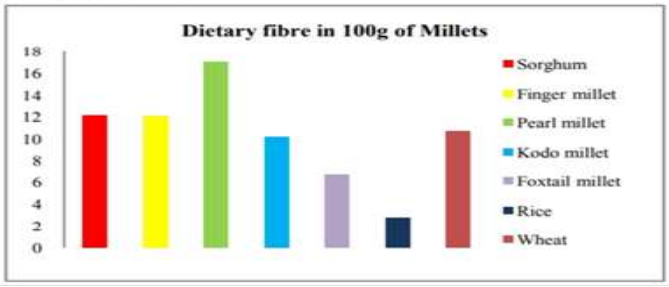
Supriya Pandey[1], Sumit Rai[1](*sumitssac101@gmail.com*), Ashish Rai[2] , Diksha Pandey[3] and Nikhil Savio[3]

[1]GB Pant National Institute of Himalayan Environment (GBPNIHE), Kosi-Katarmal, Almora, Uttarakhand, India
[2]Krishi Vigyan Kendra Parsauni, East Champaran, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India
[3]Department of Environmental Science, G.B Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

In the occasion of International Year of Millets-2023 let's understand the significance of millets in today's world. Millets are familiar to mankind since ancient times dating back to bronze age , also mentioned in the vedas they are called as super food. Millets are cereals belonging to poaceae family of grasses, they are commonly referred as coarse grains, to make everyone understand their benefits nomenclature has been changed from coarse grains to nutri-cereals. Millets are a rich source of dietary fibres, proteins, macro and micro nutrients, gluten free and have low glycaemic index(GI). They can be used in our diet and animal fodder. Millets contains iron- reduces anemia, magnesium -good for migraines, can help reduce diabetes, hypertension, prevents constipation and can help prevent heart-related diseases.

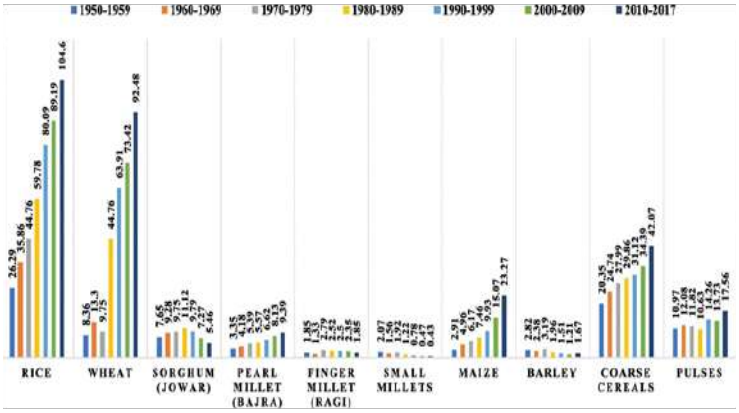


Dietary fibres present in 100 g of millets, Nutritive value of Indian foods, Gopalan

Crop / nutrient	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Sorghum	11	6.7	2.7	3.4	13
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Kodo millet	8.3	9	2.6	0.5	27
Little millet	7.7	7.6	1.5	9.3	17
Pearl millet	10.6	1.3	2.3	16.9	38
Proso millet	12.5	2.2	1.9	0.8	14
Barnyard millet	11.2	10.1	4.4	15.2	11

Nutrient value of millets,Nutritive value of Indian foods,Gopalan

With increasing awareness about it benefits, there is a great demand for millets. Millets are climate-friendly crops ,they can thrive in harsh conditions at high temperatures and require less water for their production and take less time to grow and require less fertilizers and are less prone to pests,reduces carbon food prints and imports. India has seen reduction in usage and production of millets since green revolution yet millets are still produced and consumed as many cuisines in various parts of India.



The trend in the production of food crops in India from 1950 to 2017 (in million tonnes

Growing smarter: Millet's rhizospheric ecology for climate resilience

Millets are being included in mid-day meal schemes and menus and specialized restaurants for millets based foods are emerging. Innovations in millet markets are encouraged and some of those ideas are millet seed entrepreneurs,millet aggregators,millet exporters,millet-focused farmer organizations,millet-food industry,online platforms for millet products.Millets can be brought into market as they are affordable, sustainable,climate resilient,nutritious traditional staple crop and can strengthen food security, contribute to healthy environment,provide livelihood for small-scale farmers,provide great opportunity for regional and international trade and can be used in innovative ways such as therapeutics and pharmaceuticals.

Indian institute of millet research , Hyderabad has been established for millets based research. Nutrient and health based studies are carried and have a good potential for future studies.

Nutrition and health benefits studies

R & D studies	National		International	
	Subjects	**Organization**	**Subjects**	**Organization**
Done so far	Nutrition & bioavailability of nutrients 10 biofortifield varieties developed	Nutrition profiling of cultivars (IIMR, CFTRI) Bioavailability (harvest plus India), ICAR- AICRP-IIMR	Nutritional profiling antioxidants amino acid profiling	Academia in US, Africa, Asia, R&D from Canada, Sri Lanka, China & Niger
	Health benefits & clinical evidences	Diabetics (IIMR & ICRISAT) Suitability for school children(NIN & IIMR), Bone health (ICRISAT), Metabolic syndrome (Ramaiah medical college, BLR)	CVD cancer hypertension obesity	R&D from South Korea academia China R&D from China & ICRISAT
	Degree of polishing	CFTRI, IIMR& MDRF(current project); GB Pant University of Agriculture	-	-
	Nutrigenomics	ICAR-VIHA, Almora	Nutrigenomics	Nil
	Effect of processing on nutrition	CFTRI, UAS, Dharwad		
In future	Gut microbiome & liver diseases	ILBS & IIMR	Studies to be identified by Task force on nutrition(submit by 18 Feb, 2022); functional& therapeutic studies	John Hopkins, USA, London school on hygiene & tropical medicine, UK Emory medical university, US
	Bioavailability	NIN, IIMR & CFTRI	Clinical studies for evidences of health benefits	Indian Insts: NIN, IIMR
	-	-	Gut microbiome & bioavailability studies	ICRISAT; FAO-Nutrition Wing GAIN

D.Lahari[1] (*laharidumpala@gmail.com*) **and M.D.S.R. Mohan**[2]
[1]B.Tech Student, Department of Geo-Engineering & RDT, Andhra University
[2]Research Scholar, Department of Geo-Engineering & RDT, Andhra University

Millets are a significant grain crop in the developing countries. They are particularly noteworthy since they are used as both human food and livestock feed in the semi-arid tropical regions of Asia and Africa. Millet is traditionally used for a variety of purposes, including Finger Millet, Pearl Millet, Kodo Millet, Proso Millet, Foxtail Millet, Little Millet, and Barnyard Millet (Tadele, 2019). Millets differ from other cereals in a number of morpho-physiological, molecular, and biochemical characteristics that increase their resilience to environmental stresses. The primary benefit of millets' brief life cycles—which last only 12 to 14 weeks from seed to seed compared to 20 to 24 weeks for rice and wheat—is stress reduction. Yet, traits like short stature, small leaf area, thickened cell walls, and the capacity to form deep root systems reduce the likelihood of stress situations and their impacts (Li and Brutnell, 2011). Millets have a higher nutritional value, which is one of their important characteristics. The high content of phytochemicals and minerals in millets has also been linked in studies to positive health effects. For instance, pearl millet has significant levels of antioxidant enzymes, soluble and insoluble dietary fibres, and resistant starch (Nithiyanantham *et al.*, 2019). In light of escalating agricultural costs, climate change, and a growing global population, millets are known to have great promise for food security and nutrition (Rai *et al.*, 2023). They have additional health advantages, substantially lower production input costs, and a natural resistance to the bulk of biotic and abiotic stresses. Despite growing concerns about climate change, these qualities emphasise millets as the favoured crop for the global population (Bandyopadhyay, 2017). It is necessary to create stress-tolerant, high-yielding millets in order to combat the impacts of pressures brought on by climate change and to increase millets' output. There are a number of ways to raise millets' stress tolerance and output (Numan *et al.*, 2021).

Millets have gained attention recently for their wide range of nutritional and health benefits as well as their capacity to adapt to challenging environmental circumstances, but their productivity has remained low, and it must be enhanced in order to boost its usage as a food crop globally. This review article emphasises millets' genetic potential as climate-smart crops as well as the combined effects of drought and heat on them at the same time that looming climate change is

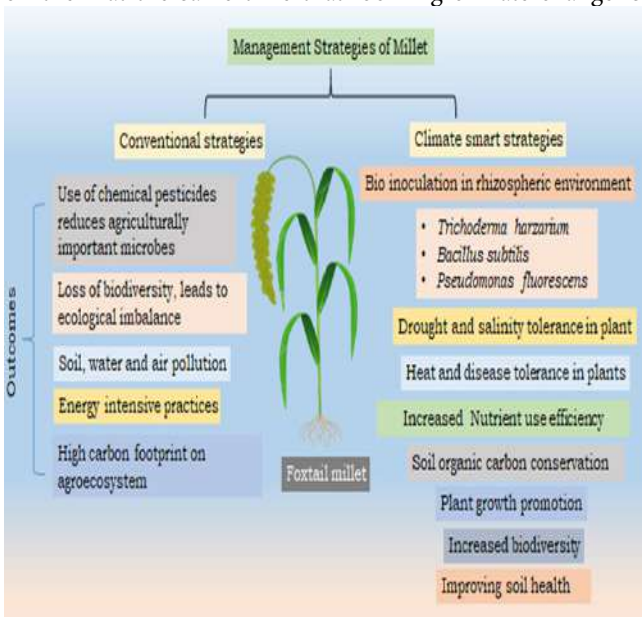


Fig. 1. Differential management strategy of millets

Traditional millet crops of Uttarakhand: present scenario and future aspects for conservation

occurring. It also makes recommendations for potential alternative strategies to improve the stress tolerance and crop production of this important class of crops. Food consumption will increase in lockstep with population growth. The likelihood of agricultural development (the production of key staple grains) is reduced because the world already faces problems with the growth of dry lands, degraded soil, and scarcity of groundwater. These sirens are compelling us to promote alternatives to grain crops.

By exerting abiotic stressors during important plant growth and development stages and causing large losses in arable area utilised for agriculture production, sudden weather shifts significantly reduced crop output. In semi-arid and arid conditions, abiotic stressors including drought, extreme temperature (cold, frost, and heat), flooding, salinity, etc. are the main factors that limit production. Millets are more resistant to environmental stresses than big grains because they possess more morphophysiological, molecular, and biochemical traits than those of major grains. Millets are better able to endure drought because they possess more morphophysiological, biochemical, and molecular traits than main grains. The current pandemic and natural disasters can teach us a lot about climate change policies and agricultural sustainability (Babele *et al*., 2022). We face a lot of similar challenges in the fight against pandemics and climate change. Regarding their cause, extent, and level of severity, these catastrophes are incredibly nebulous. A major economic imbalance and nutritional instability may arise from these uncertainties and disruptions happening at the same time.

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Ashish Rai[1], Sumit Kumar Tripathi[2], Sumit Rai[3](*sumitssac101@gmail.com*) and Rajeev Kumar Srivastava[4]

[1]Krishi Vigyan Kendra, Parsauni, East Champaran, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar

[2]Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi

[3]Centre for Environment Assessment and Climate Change, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora-263643, Uttarakhand

[4]Directorate of Seed, TCA Dholi, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar

Millets are being cultivated for around 3,000 years and are an integral part of the culture and history of India. As these millets are not only food grains; they are also intricately interwoven in the socio-cultural fabric of numerous regions of India. The millets are known to have nutrient properties low in dietary bulk, high in nutrient density and are known for their rich profile of amino acids which makes them highly nutritious crop with rich antioxidant properties for providing balanced nutrition .While millets are cultivated across the 8 states of India, Uttarakhand state ranks 3rd in aspect of the area occupied under millet cultivation. Uttarakhand has 48% area under cultivation of millets in comparison to other Himalayan states. Barnyard Millet (*Echinochloa crusgalli* P.Beauv.) and Finger Millet (*Eleusine coracana* Gaertn.) are two prominent millets in Uttarakhand which have the value chains dominated by smallholder farmers.

In India, the government is setting in place an initiative for Nutritional Security through Intensive Millet Promotion (INSIMP) through a national nutraceutical mission which has prioritized eight millets (sorghum, pearl millet, finger millet, barnyard millet, foxtail millet, proso millet, kodo millet, and little millet) and two pseudo cereals (amaranth and buckwheat) and termed them as nutri-cereals. The UN Food and Agriculture Organization (FAO), Rome has declared the year 2023 as the international year of millets, upon the request from the Indian government (Meena *et al*., 2021).

In the Indian scenario, millet production was at peak during the 1980s, thereafter it has been decreased gradually due to sharp reduction under cultivated area. Numerous steps have been taken to promote millets which include establishment of Centre for Excellence, Integration of Nutri-cereals in National Food Security Act and establishment of Millet Mission in multiple states including Uttarakhand. ICAR-CRIDA (Central Research Institute) Hyderabad has initiated NICRA (National Innovation on Climate Resilient Agriculture) project to promote millets cultivation in districts of Uttarakashi and Tehri Garhwal in Uttarakhand (APEDA, 2023).

Under millet mission 'maiden initiative' has been taken by Uttarakhand Government in which the state-owned Mandi Parishad is supposed to purchase the five types of millets and grains from farmers i.e.Chaulai (Amaranth), Madhua (Ragi), Jhangora (Barnyard millet), Kuttu/Ugal (Buckwheat) and Koni (Foxtail millet) (APEDA, 2023). The scheme has been launched in Almora and Chamoli district and will be extended to other districts in the next phase of the scheme. This initiative will directly benefit the farmer's income and motivate them to produce millets. For the women empowerment, women of the rural areas of Dehradun are given opportunities to make packaged and branded millet-based cookies, rusks, snack, and breakfast cereal and it's been selling at various platforms.

Production status of Millets in Uttarakhand: Uttarakhand state has more area under finger millet (1.08 lakh ha) and small millets (0.6 lakh ha) with yield levels per unit area surpassing the national average in both cases (Bhat *et al*., 2019). Moderate climate with relatively more fertile soils with protective moisture provisions account for the higher productivity in the state. Most of the produce in consumed in the households themselves, leaving less marketable surplus. The major districts producing millets are given in Fig. 1.

Within the recent past, some of the millet crops cultivated previously; have become locally extinct from many villages. Foxtail millet has almost become extinct from the state which was widely cultivated about 20 years ago (Kala, 2010). Lack of formal seed exchange system of traditional landraces is one important limiting factor to continue survival of these landraces especially those which are grown by marginal farmers and statistics shows that in Uttarakhand, traditional crops like finger millet and barnyard millet are getting good market. Finger millet grain yield was 6 to 7 quintals per hectare

in the year 2014- 15 whereas in 2017-18, it reached 12 quintals per hectare. Now the market is getting a decent price for these crops (Rajyasameeksha, 2018).

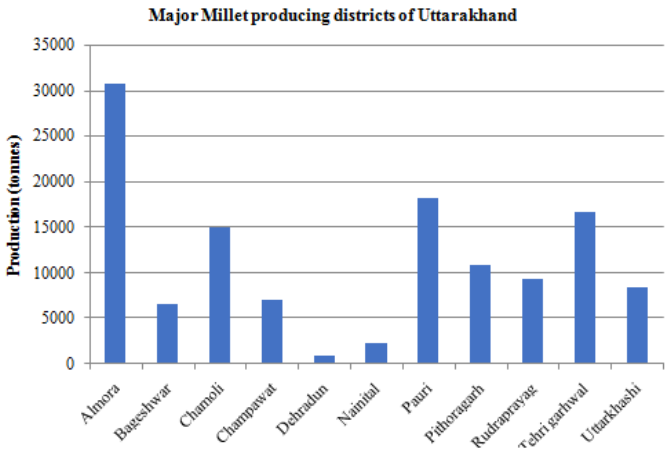

Fig. 1. The major millets producing districts in Uttarakhand (Source: APEDA, 2023)

Table 1. Traditional dishes prepared by the local people of Uttarakhand (Modified from Kala and Nautiyal 2022)

S N.	Local /botanical name of Millet as major ingredient	Name of local Dish	Preparation Style	Ethno-medicinal and cultural values
1.	Jhangora (*Echinochloa frumentacea*)	Pinda/ chatna	Jhangora is cooked in water like rice mixed with water	Used to cure constipation in cattle.
2.	Jhangora (*Echinochloa frumentacea*)	Kheer	Jhangora is cooked in milk mixed with sugar/jaggery	Easily digestible and alternative of sweet dish
3.	Koni (*Setaria italica*)	Pinda	Koni is cooked in water like the one cooks rice mixed with water	Considered highly nutritious and used to cure indigestion
4.	Mandua (*Eleusine coracana*)	Mandua ki roti	Mandua flour is kneaded with water to make dough. It is used to make chapattis	Highly nutritious and contains a high quantity of calcium and other nutrients. Traditional healers recommend it to cure bone-related disorders and also to cure sinus and severe cold
5.	Jhangora (*Echinochloa frumentacea*)	Palyun	Jhangora is cooked with water and buttermilk/ sugar/water	Easily digestible and used as a stomach tonic
6.	Mandua (*Eleusine coracana*)	Badi	Mandua is soaked overnight and grinded with water and spices to form button shaped parts which are sun dried and fried	Cooked as a staple of pulse in winter season.
7.	Mandua (*Eleusine coracana*)	Baadi/	Mandua is grinded and cooked with sweet and ghee	Cooked as a warming food in winter season
8.	Jhangora (*Echinochloa frumentacea*)	Jhangore ka bhat	Jhangora is cooked in water like the one cooks rice mixed with water	Easily digestible and used as a substitute for rice in the areas where rice does not grow
9.	Jhangora (*Echinochloa frumentacea*)	Jhangore ki sabji	Cooked with kandali /bicchu ghas/stinging nettle (Urtica dioeca Linn) and mixed with water	Easily digestible and used as a stomach tonic in winter season

Future perspectives for millet production: Multi-sectored national and international multidisciplinary initiatives are required for the promotion and enhanced consumption of these important millet crops. Furthermore, linking small millets to the industry through value addition will fetch higher returns to marginal farmers. The quality enhancement of the existing dishes for the development of market based demands is also required. The social media and web based marketing of the certified products can also be enhanced under government supervision so that the beneficiaries can be benefitted directly by selling their products to the appropriate consumers, for which governmental guidelines can be developed. Furthermore the sensitization and capacity building of the existing stakeholder which have been actively engaged in the cultivation of millets need to be enhanced for the development of variety of products.

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Honey Bhatt[1], Harshit Pant Jugran[1] (*drharshitpant@gmail.com*) and Ashish Jugran[2]

[1]Centre for Socio-Economic Development (CSED) ,GBPNIHE, Kosi- Katarmal, Almora-263 643, Uttarakhand, India

[2]Ajim Premji Foundation, Pauri-Garhwal, Pauri-246001,Uttarakhand, India

Kodo millet: A superfood for healthy life

Millets are collective group of small seeded annual grasses. Millets are known as nutricereals since they are the powerhouse of nutrients. The majority of millets are three to five times more nutritious than major cereals (rice, Oryza sativa; wheat, Triticum aestivum; maize, Zea mays) in terms of vitamins, fiber, proteins, and minerals and are gluten-free; hence, they are known as "superfoods" (Ashoka *et al*., 2020). Millets are classified into major millets and minor millets as represented in Table 1. These are grown as grain crops in dry areas of temperate, subtropical and tropical regions. Millets hold great potential in contributing substantially to food and nutritional security of the country, thus they are not only a powerhouse of nutrients, but also climate resilient crops with unique nutritional characteristics. These grow with minimal application of fertilizers and pesticides. Water requirement for millets is also low. These are used as food, feed, fodder and biofuels. In India, from 1951 to 2020 there is 35% decrease in cultivated area under millets, however the total production has increased 3 times, i.e. from 15 million tons to 47.48 million tones.

Table. 1. Types of millets

Millet	Scientific name	Name in Hindi
Major millets		
Pearl millet	*Pennisetum americanum*	**Bajra**
Finger millet	*Eleusine coracana*	**Ragi**
Sorghum millet	*Sorghum bicolor*	**Jowar**
Minor millets		
Foxtail millet	*Setaria italica*	**Kakum**
Proso millet	*Panicum miliaceum*	**Chenna/Barri**
Kodo millet	*Paspalum scrobiculatum*	**Kodon**
Little millet	*Panicum sumatrense*	**Kutki/Shavan**
Barnyard millet	*Echinochloa frumentacea*	**Sanwa**

Kodo millet also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass is grown in India, Pakistan, Philippines, Indonesia, Vietnam, Thailand and West Africa. It is major food source in the Deccan plateau of India (Gujarat, Karnataka and parts of Tamil Nadu), some regions of Maharashtra, Odisha, West Bengal, Rajasthan, Uttar Pradesh and Himalayas and consumed traditionally as health and vitality foods in rural India. The local names of Kodo varies from region to region and it is known as Kodo in Bengali, Kodra in Gujarati, Punjabi and Marathi, Kodon in Hindi, Harka in Kannada, Koduain Odia, Varagu in Tamil and Arikelu, Arika in Telugu. It is an annual grass species that grows to around 90 cm height. Kodo millet grain color varies from light red to dark grey which is bounded in a tough husk that is difficult to remove. Kodo millet is well known for the highest drought resistance among all minor millets and said to produce good yield with in less growing period, i.e. 80-135 days (Saxena et al., 2018).

Nutritional value of Kodo millet: Kodo millet does not contain gluten, which makes them an appropriate food for those suffering from celiac disease or other forms of allergies/intolerance of wheat. Beside, due to their high fiber (9.00 g/100g) and mineral (2.60 g/100g) contents, they can contribute significantly to the nutritional security of large section of population and a good substitute to rice or wheat. The proximate composition of Kodo millet and other major cereal crops (wheat, rice and maize) is shown in Table 2.

Kodo millet protein is rich in various amino acids namely phenylalanine, methionine, cysteine, threonine, leucine, isoleucine and valine. The contents of these amino acids are higher in Kodo millet as compared to rice, wheat and maize (Table 3). Minerals like Mg, S, Cr and C are present in higher amount in Kodo millet as compared to rice, wheat and maize (Table 4). Kodo millet is also a rich source of folic acid (39.50 µg/100 g), thiamine (0.30 mg/100 g), riboflavin (0.20 mg/100 g) and niacin (1.50 mg/100 g).

Kodo millet contains antinutrients viz., phytic acid, polyphenols and tannins. These antinutrients combine with nutrients, thereby impairing their absorption, digestion, and consumption. Kodo millet contains 225.00 mg/g phytic acid, 143.00 mg catechol equivalent/100g polyphenols and 50.40 tannic acid equivalent/100g tannins. Antinutrients can be reduced through various treatment methods such as soaking, germination/ sprouting, cooking, malting, and fermentation of the grains. However, research has proved that antinutrients consumed in sufficient quantities

Table. 2. Proximate composition of Kodo millet and other major cereals (all values are per 100 g of edible portion)

Name of the food stuff	Moisture (g)	Protein (g)	Fat (g)	Minerals (g)	Crude fibre (g)	Carbohydrates (g)	Energy (kcal)
Kodo millet	12.80	8.30	1.40	2.60	9.00	65.90	309.00
Wheat	12.80	11.80	1.50	1.50	1.20	71.20	346.00
Rice	13.70	6.80	0.50	0.60	0.20	78.20	345.00
Maize	14.90	11.10	3.60	1.50	2.70	66.20	342.00
Source: Gopalan et al., 2004							

Table 3. Status of amino acid profile (mg/g N) of Kodo millet and other major cereals

Name of the food stuff	Arginine	Histidine	Lysine	Tryptophan	Phenylal-anine	Methi-onine	Cysteine	Threo-nine	Leucine	Isoleu-cine	Valine
Kodo millet	270.00	120.00	150.00	50.00	430.00	180.00	110.00	**200.00**	**650.00**	**360.00**	**410.00**
Wheat	290.00	130.00	170.00	70.00	280.00	90.00	140.00	**180.00**	**410.00**	**220.00**	**280.00**
Rice	480.00	130.00	230.00	80.00	280.00	150.00	90.00	**230.00**	**500.00**	**300.00**	**380.00**
Maize	290.00	160.00	200.00	40.00	290.00	120.00	100.00	**280.00**	**720.00**	**240.00**	**300.00**
Source: Gopalan et al., 2004											

can reduce the risk of certain diseases, such as breast cancer, coronary heart disease, and inflammation.

Table 4. Status of trace elements (mg per 100 g) in Kodo millet and other major cereals

Name of the food stuff	Ca	P	Fe	Mg	Mn	S	Cr	Cu
Kodo millet	27.00	188.00	0.50	147.00	1.10	136.00	0.020	**1.60**
Wheat	41.00	306.00	5.30	138.00	2.29	128.00	0.012	**0.68**
Rice	10.00	160.00	0.70	90.00	0.59	-	0.004	**0.14**
Maize	10.00	348.00	2.30	139.00	0.48	114.00	0.004	**0.41**

Health benefits of Kodo millet: Kodo millet contains balanced nutritional composition and its consumption has proven health benefits. Kodo millet is very easy to digest and thus can be beneficial for infant and geriatric product formulation. Kodo millet contains a high amount of lecithin and is excellent food for strengthening the nervous system. Kodo millet contains no gluten and is good for people who are gluten intolerant. Regular consumption of Kodo millet is very beneficial for postmenopausal women suffering from signs of cardiovascular disease, like high blood pressure and high cholesterol level.

Development of value added products using Kodo millet: The improved value addition expertise has created various opportunities for the food processing industry to manufacture quality millet based products having wider consumer acceptability. Various value added products such as blended flour, baked products, fermented products, puffed/popped and flaked millets and extruded products are prepared from Kodo millet. It is evident that Kodo millet is a superfood that possesses equivalent health benefits and nutritional value like major cereals like rice, wheat and maize. However, technological advances should be worked out to enhance its acceptability in consumers in terms of quality, nutrition and functionality. So, research is needed for development of better quality Kodo millet products that should be health promoting, tasty, possess long shelf life, attractive in appearance and affordable for all income group consumers.

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Meenakshi Thakur (*thakurmeenakshi94@gmail.com*)
and Preeti Chaudhary
College of Horticulture and Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry Neri, Hamirpur, H.P.

Millets were among the first crops to be cultivated by mankind about 10,000 years ago,these forgotten treasures of ancient civilization are now new solace for a world confronting challenge of food security due to climate change, disrupted global food supply chain caused by pandemic and Russia-Ukraine crisis. Millets or nutri-cereals are the promising magic bullets as are nutritive , energy efficient and highly climate resilient. Millets have potential to assist in achieving multiple UN (United Nations) sustainable development goals (SDGs) no wonder UN General Assembly (UNGA) declared 2023 as international year of millets after strong advocacy of India. Time is reap to leverage the potential of these indigenous dryland cereals as source of food and fodder to nab hunger and lifestyle diseases by fostering its cultivation, promoting research, innovations in developing high yielding varieties(HYVs),biofortification and giving impetus to start-ups, entrepreneurship, policy intervention for processing, marketing and value addition. The icing in the cake will be creating a regular market base with affordable pricing and consumer awareness making it routine diet in every dine. However, while promoting millets precaution shall be taken in improving its shelf-life, per hectare yields understanding its metabolism and threats related to food allergies. For ever growing human population prolonged and affordable supply of food is a daunting task.Though green revolution gave impetus to tremendous production of wheat, rice and maize but these carbohydrate enriched cereals paved way to several life style diseases and also failed to tackle hidden hunger causing several deficiency diseases from anemia to rickets, marasmus etc.

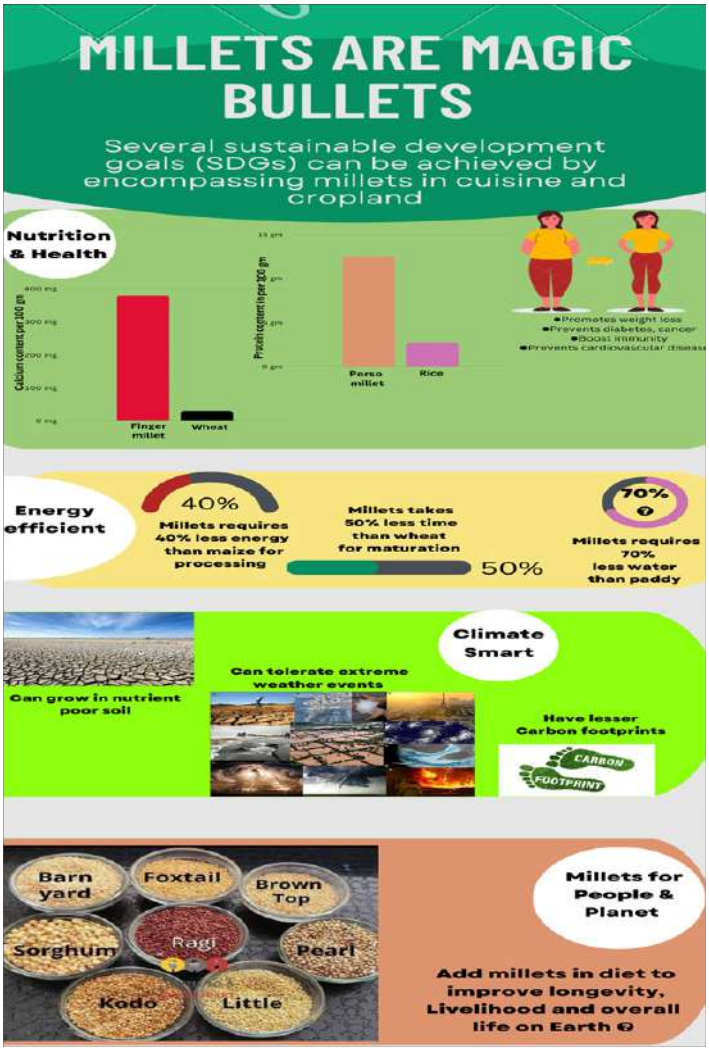

Fig. 1. Displaying marvels of mighty millets

Millets or shree-anna (as named so in 2023 union budget of India) have greater quantity of dietary fibres, high quality gluten free protein with several essential amino acids and poly-phenols, anti-oxidants, iron, calcium, zinc,magnesium ,omega-3 fatty acids, vitamin B complex that help assure proper growth, development, fitness, strength and performance of body and brain. It is established that just replacing 20% of staple cereals with millets can make huge difference in improving physical and mental well being.Thus can help fulfilling SDG 2 (Zero hunger) and SDG 3 (Good health and well being) "Let thy food be thy medicine" a quote often ascribed to Greek physician Hippocrates can fully be realized by encompassing millets in everyday meal. Apart from acting as source of calories and tackling deficiency diseases millets are also impactful in dealing life-style diseases. The fibre enriched millets are slow to metabolize thus ensures delayed emptying of stomach a crucial factor ensuring weight loss. The foxtail, little millets, kodo have low glycemic index and thus are preventive against type 2 diabetes. Several millets are known to lower blood triglycerides important in mitigating cardio vascular diseases. Millets like foxtail and porso are effective against cancerous growth. Deriving from concept of "One health" SDG 2 and SDG 3 vastly relies also on accomplishment of SDG 12 (Responsible consumption and production) and SDG 13 (Climate action) and millets are critical link in assuring the same. For when it comes to energy use efficiency millets are hands down better performer than for example maize as requires 40% less energy in processing. Millets demands 70% less water vis-a-vis water guzzling paddy. The per hectare fertilizer demand is also low for these hardy crops and are known to grow well in vast range of altitude and latitude in poorly fertile, saline,acidic soil. In age of global warming and climate change when wheat and rice are facing uncertain and irregular production, millets the highly adaptable coarse grains are pivotal for evergreen revolution with potential of mitigating climate change as for instance the carbon footprints of millets is 25% less than that of wheat. Millets also can tolerate weather extremes and ensure sustained productivity with minimal fertilizer demands. The major challenge in popularity of millets is lack of awareness and lack of value addition. Its important to make it people's movement through several outreach policies and programs.One such is compulsorily introducing millets in mid day meals, Public distribution system. Making millet cultivation lucrative by raising minimum support price (MSPs), promoting entrepreneurship and start-ups for its processing, marketing and value addition. Focus shall also be on accelerating research and innovation in developing its high yielding varieties, fortification, disease resistance etc. However in a bid to revive millets to main course one shall not forget that millets are not panacea for everything our body demands. Given their slow digestion it can't deliver energy as swiftly as rice. Also owing to high fiber content millets requires more water ,time and energy in cooking. Amid cost benefit analysis of millets one can easily conclude that millets are here to stay as integral part of our food and foster human resource development, well being of the planet in just, sustainable and inclusive way.

Mugdha Kumari Pandey

Department of Zoology, JPM college, Chapra, Bihar, India

Relevance of Local Governance for protection and promotion of indigenous agricultural products in local areas: A conceptual review

Local ecosystems and biodiversity play an important role to ensure the agricultural production of that area, so the protection of biodiversity is very much important.Some of the unique agriculture/horticulture products are only used to grow in certain areas only like Manipuri Black rice, Gobindobhog rice in West Bengal, Queen Pineapple of Tripura,Sitahi little millet, Nagdaman little mille in Dindori district of Madhyapradeshand most these products are recognized with Geographic Indication (GI) label. Therefore, the "terrestrial ecosystem or biodiversity" of the defined area is the fundamental "enabling element" that guarantees the sustainability of all these indigenous agriculture /horticulture products to date. Considering the geographical uniqueness, the country is the home of a lot of indigenous agricultural products and enjoys great biodiversity or ecosystem with 3% biodiversity hot spot, 200 eco-regions, 8% all recorded species in the world, 45,000 plant and 91,000 animal species fully or partly belongs to India (IUCN, India 2018). But it is unfortunate that biodiversity degradation is very much rampant which creates a threat to the sustainability of all indigenous products. Now, there is an urgent need to call for appropriate action against biodiversity degradation at all levels especially local level action is very much required. The study employs secondary data with a qualitative research approach with the researcher's experiences and it seeks to understand the role of local governance in the conservation and rational use of local ecosystems for climate change adaptation and reduce environmental degradation through the promotion of sustainable and indigenous agricultural practices in local areas. Green Revolution resulted in India to a food surplus country from a deficit one but on the other side, it also led to an overall degradation of the fragile agro-ecosystem (Rahman 2015) in long run. So, on one side Green Revolution has a positive impact as it fulfills the huge requirement of food considering India's population explosion, and another side it has a negative impact like erosion of soil, loss of soil fertility, soil toxicity, loss salinity and pollution of groundwater resources, increased incidence of human and livestock diseases, etc. (Rahman 2015). So, the green revolution's impacts and benefits have been unequal across regions and groups. It also needs to state that Post-Green Revolution, wheat, and rice production was doubled, but a significant decline was noted in the production of other food crops such as indigenous rice varieties, millets, etc. and it resulted in the loss of distinct indigenous crops from cultivation and caused the extinction of many indigenous agricultural products (Nelson, Ravichandran, and Antony 2019).

In addition, there are end no of instances and evidence which means that the environment is under serious threat and biodiversity degradation is a common phenomenon in all areas. The rate of environmental degradation can knock down the whole environment very soon (Anup 2015) and if the concerns of the environment have not addressed urgently, the effects of environmental degradation can demolish the whole environment(Shah, 2005). So, the sustainability of indigenous agricultural products is under serious threat where unsustainable and destructive human behavior and harvesting practices are also a major concern. Now, this is high time to take the necessary measurement at the local level to stop environmental degradation for the protection and promotion of local indigenous products like millet. Keeping in mind the diversity of India's climatic differences, seasonal variances, soil qualities, and water, it is impossible to initiate an undisputed and foolproof programme for development aspects specific to indigenous agricultural products. Here, the researcher feels that the active involvement of local government and its associated frameworkcan play a major role at the grassroots.

Nexus between environment and local governance framework: Engagement of all levels of government is very much important to tackle various issues of climate change and action (COP21). Local-level government is the best institutional framework to address risk

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and climate change action as it is pluralistic, contextual, and adoptive, so the need and urgency of local government are beyond debate (McArdle, 2016). Local bodies are statutorily responsible to make biodiversity plans by using local knowledge (Evans, 2004). So, to protect and rationalize the utilization of the ecosystem, a citizen-led good governance system is required at the grassroots level which can address existing and emerging issues of the ecosystem and indigenous agricultural products. Here, the researcher feels,i.e. Gram Panchayat/ Village Council and other associated frameworks like Biodiversity Management Committee (BMC), Joint Forest Management Committee (JFMC) Gram Sabha, Village Health Sanitation and Nutrition Committee, local NGOs, CBOs, SHGs, Youth Clubs in rural areas can play a significant role in the issue for ensuring sustainable solutions towards the promotion of indigenous agricultural products in a balanced manner.

Probable major role of Local Governance:

Strengthening the local market with locally grown products so that people of the area will be encouraged to cultivate indigenous crops.

Panchayat needs to play an active role in the Implementation of the Biodiversity Management Act 2002 especially the Constitution of the Biodiversity Management Committee and the preparation of the People's Biodiversity Register at the Panchayat Level. Identification of all biodiversity spaces, agroecological zones, and existing environmental resources of the concerned gram panchayat is very much needed.

Elected Panchayat Raj Institutions (PRIs) members and Government functionaries need to work together for the conservation of the local ecosystem with the promotion of indigenous agricultural products in their concerned area.

Local Government should ensure awareness among the community and various influential groups of the society for the conservation and sustainability of the local ecosystem and environmentwhich may ensure enabling environment for the promotion of indigenous products like millet and others.

Conclusion: Indigenous agricultural products are the roots of the Indian agricultural system but due to many reasons, it has been ignored for a long time. Government, whether it is central or state, development organizations, and others have already done many experiments on agriculture but there are very few models which are sustainable so to ensure the sustainability of the indigenous agricultural product we need collective responsibility on the part of all stakeholders at the local level, particularly from the local government and associated framework of local governance.

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Santanu Bhowmick (*santanu.raikol@gmail.com*)
Department of Local Governance, Rajiv Gandhi National Institute of Youth Development, Ministry of Youth Affairs and Sports, Government of India, Sriperumbudur

At current scenario, climate changes are alarming which results in extreme weather events and thus impacting the food security and nutrition.Fishery, agriculture, and livestock are declining. Oceans and seas which nourishes millions of human beings are at risk as the sea water acidifies. Variations within ice and snowpossessinfluence onfood sources including cattle livestock, poaching, and fishing in manyfrosty polarregions.Extreme heat can reduce water and grassland for grazing, leading to decreased agricultural and livestock mortality.Climatic changes forecasted to affect major crop production up to 30% owing to decreased yield and crop failure(Acevedo *et al*., 2020). If all these climate changesare increasing continuously at current rate, it will hamperin achieving the United NationSustainable development Goal-2 (SDG-2)to eradicate hunger and malnutrition.

What are Climate Resilient Crops: Climate-resilient crops are crops and theirvarietieswhich have increased tolerance to extremeweather events and also resistance to stressfulenvironmental conditions (bothabiotic such asheat, drought, flooding, chilling,salinityand biotic such as insects and pests)and thereby able to maintain or increase crop yields under these stressful conditions. Important climate resilient crops are millets, sorghum and quinoa.Climate resilient crops provide a means to overcome decreased crop productivity by absorbing, adapting and recovering from the impacts of extreme weather and climate change events.

Millets- An Overview: Millets are collection of small cereal grains which belongs to grass family i.e., Poaceae or Gramineae. Important varieties of millets include sorghum, pearl and finger. Millets are arid and semi-arid crops that can be cultivated in tropical and sub-tropical climatic conditions up to an ofaltitude of 2,100 m.Millets have a short lifespan of 2 to 4 months. Millets grows during kharif season between the months of April and May. Millets grow best at temperatures ranging from 26-29°C for maximum productivity and crop output. It is cultivated in areas with rainfall ranging from 500 to 900 mm.

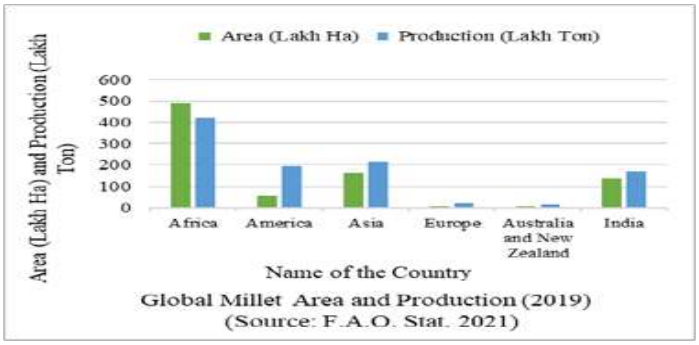
Millet- A Futuristic Climate Resilient Crop: Millets called as dry crops as theythrive on degraded dry soils which are less fertile and requires minimum amount of rain or irrigated waterto grow. These crops can withstand considerable alkaline soil and adapt well to a wide range of soil types, from extremely poor to highly fertile. These properties of millets make them widely renowned for their drought and salinity resistance under harsh or dry conditions.

Millet biochemistry developed over centuries to be become climate-resilient, covering both abiotic and biotic stress. Physiologically,millets are members of the C4 plant family, that have developed by itself more than 500 times. Millet being a C4 plant have higher photosynthetic efficiency which enables them in absorbing and utilizing more CO_2 from atmosphere by minimizing photorespiration (by using Phosphoenolpyruvate (PEP) enzyme). Also, the potential yield of millets, remains unaffected even at high CO_2 levels as compared to C3 crop like wheat and rice etc. which only have meristematic cellswhich absorb light (origin of photosynthesis) and no chloroplasts. On the other hand,C4 cropsdeveloped additional photosynthetic chambers: mesophyll cells and bundle sheath cells.These two factors improve the photosynthetic efficiency of C4 plants. All these properties make millet a truly climate resilient crop.

Millets- Origin, Production and Distribution: Archaeobotanical data of India suggests there were most probably many separate centres of indigenous millet production in South Asia. The Panicum miliaceum(Proso millet) was the very first such grain, dating back to the pre-Harappan period or during the first part of the second millennium BC, and was widely farmed in Gujarat, among other places. The evidence for Panicum sumatrense(small millet), a staple crop of protohistoric Gujarat and a crop of the eastern Harappan zone.However, *Brachiaria ramosa*(Browntop millet)was the earliest staple millet in south India, and has also

been identified as an earliest crop/resource in the Neolithic Ganges. They were cultivated in the Neolithic era to provide humanity with a prolonged growth season since they were suitable to all weather conditions. As a result, millet became a mainstay for our forefathers, ensuring food security. Millets were described in some of the earliest Yajurveda books in India, naming foxtail millet (Priyangava), barnyard millet (Aanava), and black finger millet (Shyaamaka), showing that millet usage was widespread prior to the Indian Bronze Age (4,500BC). India is the world's largest producer of millets contributing 20% of total world production. Among Asian countries, India accounts for about 80% total millet productionwhich is the highest. The FAO's goal for 2023 is to raise awareness of millets in food security and nutrition. The important millet cropsthat grownin India are *Sorghum bicolor*(Sorghum), *Pennisetum glaucum*(pearl millet), *Eleusine coracana*(finger millet), *Setaria italica*(foxtail millet/Italian millet), *Panicum sumatrense*(small millet), *Paspalum scrobiculatum*(kodo millet), *Echinochloa esculenta*(barnyard millet), *Panicum miliaceum*(Proso millet), and *Urochloa ramosa*(brown top millet) Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Odisha (minor millets), Andhra Pradesh, and Uttarakhand are the leading millets-producing states in India.

Millets in the Indian Himalayan Region(IHR): The Himalayan agro-climatic regions vary from warm sub-humid tropical to temperate, alpine, and glacier. About 85% of the Himalayan population rely on conventional mixed hilly agriculture, livestock farming, agroforestry, and forestry for their survival. Millets have been cultivated and consumed in the Indian Himalayan region (IHR) since ancient times.In Indian Himalayan Region (IHR), finger millet is the most common and adaptable millet, followed by foxtail millet. Barnyard millet is predominantly grown in Uttarakhand, although bajra and jowar are grown in a few regions of Jammu and Kashmir and Himachal Pradesh. In certain states, proso millet is grown in little packets. In Arunachal Pradesh, Millets have a high cultural usefulness, but in stateslike Assam and Tripura do not include millets.



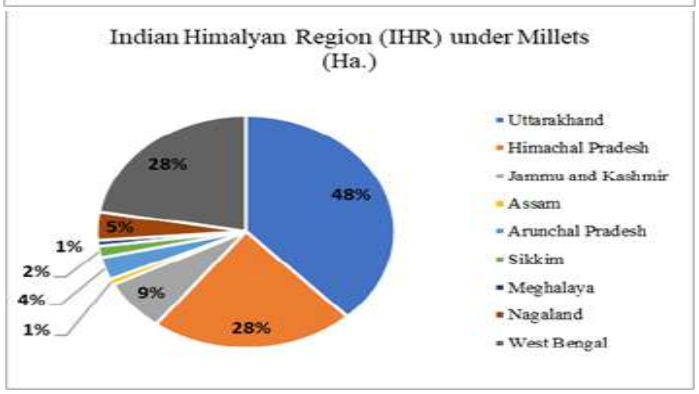


Fig.1. Graph showingGlobal Millet Area and Production (2019) and Pie-Chart indicating Millets distribution in Indian Himalayan Region (IHR) Respectively

Millets:-Health andNutritional Benefits: Millets are highly rich in nutrients.Millets are an excellent source ofbeta-carotene(vitamin A), vitamin B, phosphorus, potassium, antioxidants, niacin, calcium, iron. Niacin, found in millet, helps your body to regulate over 400 enzymatic processes. Niacin is also necessary for good skin and organ function.Beta-carotenepigment found in millets functions as an antioxidant as well as a precursor of vitamin A, boosting your body in fighting free radicals and promoting eye health.Millet has additional health advantages such as in controlling of blood sugar (asit a low-glycemicindex (GI) food),improve digestive health (as it contains insoluble fibre called as prebiotic which improves gut health),protectsheart (by reducing the amount of badcholesterol in your blood which is a risk factor for atherosclerosis).Millet is high in potassium, a mineral that promotes kidney and heart health. It also involved in nerve signal transmission, which is how your brain and muscles interact with one another.A 3/4 intake of dried millet provides the following nutrients:- 189 grams calories, 6 grams of protein, 2 grams fat, 36 grams carbohydrates, 4 grams of fibre, less than 1 grams of sugar. All these nutritional and health beneficial qualities of millets, make it a superfood of present as well as future time (Sachdev, 2022). Due to nutritional and health benefits of millets, this superfood should be included in our daily life for once in a week.Therefore,in order to focuses onproduction, promotion, consumption, health and nutritional benefits, and alsoraising awareness aboutit, the United Nations announced "International Year of Millets 2023"at the request of the Government of India.

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Saurabh Kumar (*s.singh100nlgmail.com*) **and Sachitra Kumar Ratha**

CSIR- National Botanical Research Institute (NBRI), Lucknow (Uttar Pradesh), India

Climate smart millets: A way to ensure sustainable nutritional security

600 million people in India depend on agriculture, the most of them are small farmers with holdings of up to 2 hectares of land. All around the world, agricultural output, food stability, and nutritional security are being impacted by climate change. Shorter grain filing periods, poorer yield, and reduced biomass are the results of climate change's detrimental effects on plant growth, including as higher temperatures, more frequent and intense rainfall, and less rainfall during crucial crop phases. Moreover, abiotic stresses tend to compound upon one another. The uptake of nutrients by plants is hindered by factors such as high temperatures, which lead to quick evaporation and dry soil, thereby reducing the amount of water available to plants. India's agricultural sector is also feeling the heat of the climate catastrophe. As a result, millets are old-fashioned crops that boast superior nutritive value and health advantages. Millets are ideal crops for the twenty-first century as we face depleting natural resources and climate change due to their climate-resilient characteristics such as adaptation to a wide range of ecological conditions, reduced irrigation demands, improved productivity and growth under low nutrient input conditions, less reliance on synthetic fertilizers, and low vulnerability to environmental stresses (such as drought and flood) (Henry, 2015). Millets are also more nutritious than other major cereals because they have a lot of dietary fibres, resistant starches, vitamins, essential amino acids, storage proteins, and other bioactive compounds. (Amadou et al., 2013). Millet doesn't get stressed because it doesn't take long for it to go from seed to seed. Rice and wheat, on the other hand, can take up to 24 weeks to go from seed to seed. Because of these qualities, millets are a popular crop in dry and semi-dry areas around the world. Millets, on the other hand, haven't been studied as much as other major cereals in terms of their ability to adapt to climate change. (https://www.frontiersin.org/articles/10.3389/fpls.2017.01266/full). Millets are required as the climate crisis deepens because they can be grown in the most difficult conditions and can fill the gap in supply from rice and wheat due to the severe consequences of climate change. Higher photosynthetic efficiency and potential yields that are unaffected by increased Co2 levels distinguish these anatomically better C4 crops from C3 crops like rice and wheat. India is the world's largest producer and second-largest exporter of millets, producing nine commonly known millets (Fig. 2, Table 1).

with both early and delayed planting, very low and high rainfall, various elevations, and a variety of soil regimes. These positive traits have not been fully appreciated and applied throughout the nation. Multiple-purpose millet varieties, like foxtail millet, barnyard millet, proso millet, and tiny millet, are able to adapt to climate changes and shield farmers from a total crop failure. Given a secure market, farmers who had previously shifted from millets to other crops are willing to go back to millets because of the guaranteed stable yield, simple crop cultivation, resistance to drought, and environmentally benign production.

Millets for Climate–Smart Agriculture: The demand of food consumption is rising proportionally with a growing population.As a result, millets are the best alternative among orphan crops because they can be grown on shallow, low-fertility soils with pH levels ranging from 4.5 to 8.0 (Rathinapriya et al., 2020).Finger millet and pearl millet can grow in soils that are as salty as 11–12 dS/m, but soils with more than 3 dS/m of salt are not good for growing rice. They are called a "poor man's crop" because they are important to the diet of a population with few resources and because there are many ways to grow them (Fig.1).

Millets have been termed to as nutria-cereals or smart food because they are better adapted to diverse environmental conditions due to nitrogen-use efficiency and water use efficiency, insect, pest, and disease tolerance, and resistance to environmental stresses.

In Asia, particularly India, millets are regarded as a climate-resilient future crop. They can grow in almost any soil type, whether sandy or with varying levels of acidity. They rarely need irrigation or fertilizer.Millets can help to sustain food systems in the context of global warming. Their adaptability and exceptional ability to survive in low water availability and stressful environments make them the best alternative to climate change (Table 2).

Role of the Government in Millets Promotion: In this changing climate scenario the Government of india has realized the importance of millets in building resilient to climate change and building nutritional security in the country. The Government made various efforts such as gazatting millets as Nutri-cereals, the declaration of the National Year of Millets in 2018 and declaration of international year of millets by UNGA with India along with 70other nations. It is an important step in popularizing millets. The following are the some initiatives and schemes

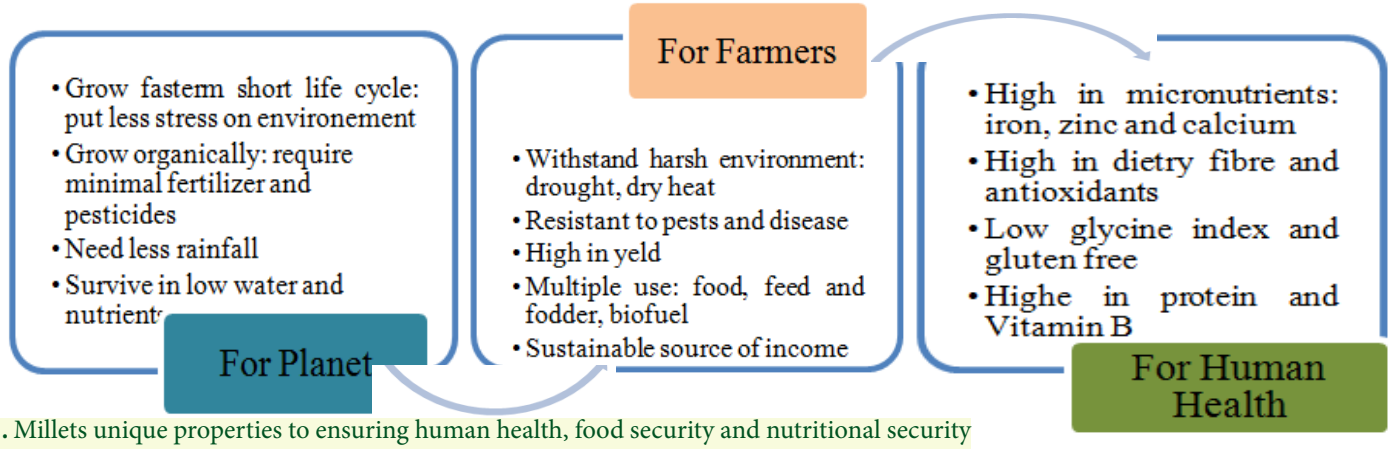

Fig. 1. Millets unique properties to ensuring human health, food security and nutritional security

Millets are the future crops: Millets provide a strong argument for increasing biodiversity and diversifying the world's food grain supply due to their variety and capacity to adapt to a variety of climatic conditions and agricultural methods.Because millets are climate change resistant and provide sustainable grain production with few inputs, they are the most reliable and constant food crops for humans in a scenario of climate change, particularly for the world's resource-poor dry-land farmers. (Rao & Basavaraj, 2015).Millets crops are excellent candidates for climate change mitigation and emergency crop planning due to their wide variety. They can grow in environments

taken by Government of India and the state Governments to promote production of millets across the country.

- Initiative for Nutritional Security through Intensive Millets Promotion.
- Providing farmers with a significant price incentive
- Millet Startup Innovation Challenge
- POSHAN Mission Abhiyan
- Mann Ki Baat
- National Nutri Cereals Convention 4.0

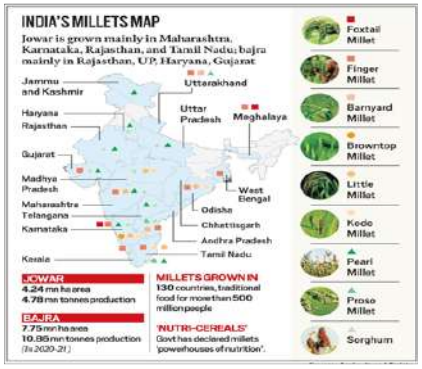

Fig. 2. Production of Millets in India. (Source:https://www.insightsonindia.com/wp-content/uploads/2022/11/millets.png)

Table 1. List of Millets produced in India

Sr. No.	Millets Name	Scientific Name
1.	Sorghum	*Sorghum bicolor*
2.	pearl Millet	*Pennisetum glaucum*
3.	Finge millet	*Eleusine coracana*
4.	Barnyard Millet	*Echinochloacolona*
5.	Proso millet	*Panicum milaceum*
6.	Foxtail millet	*Setariaitalica*
7.	Little millet	*Panicum sumatrense*
8.	Kodo millet	*Paspalum scrobicultum*
9.	Brown top millet	*Urochloa ramose*

Since rice and wheat were grown on a much larger scale as a result of industrialization and urbanization, millets' importance and cultivation were reduced. Millets have reemerged as a viable option for maintaining a healthy diet and adaptive measure in the changing climate.Increasing millet cultivation is urgently needed because the area under these crops has been declining over the past 50 years. Research programs that can enhance existing cultivars for desired characteristics, such as high yielding seeds, seeds that are resilient to abiotic and biotic stress, seeds that offer high biomass for fodder, etc. Farmers should be made aware of enhanced millet seed resources through demonstration and extension activities.

Table 2. Climate Resilient Millets and adaptation

Sr No.	Crop Name	Climate	Crop duration (days)	Av. Yield (kg/ha)	Adaptation for impacts of climate change
1.	Finger Millet	Wide adaptation up to 2300 m	90-130	1226	Moderatly resistant to heat, drought and humidity, adapted to wide altitude range
2.		Wide adaptation Up to 2000m	70-120	565	Adapted to low rainfall, high altitude
3.	Kodo millet	Tropic/ Sub-tropic up to 1800m	120-180	312	Long duration, but very hardy, needs little rainfall, comes up in very poor soils, good response to improved management
4.		Wide adaptation Up to 2000m	45-60	857	Very short duration, not limited by moisture
5.	Little millet	Tropic/ Sub-tropic up to 2100m	70-110	349	Adapted to low rainfall and poor soils condition, used as famine food and can withstand water logging to some extent
6.	Proso millet	Wide adaptation Up to 3500m	60-90	323	Short duration, low rainfall

G.B. Pant NIHE took an initiative in view of the Climate smart Seed Bank, in which marginalized farmers of transformative site were aware and trained on Climate Resilient seed.In this program climate resilient seed bank was developed in the panchayat to enhance the adaptability of the marginalized farmers towards the climate change.

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Twinkle Thakur and Kesar Chand *(kesar1982@gmail.com)*
GB Pant National Institute of Himalayan Environment,
Himachal Regional Centre, Mohal-Kullu,
HimachalPradesh, India

Millets for food security: Production, consumption, and development of market and value chain - A review of research and development activities

Millets are small-seeded grains that are used as staple food in many regions of the world. They are drought-resistant, have a short growing season, and are highly nutritious, making them ideal for cultivation in arid and semi-arid regions. Millets have been grown for thousands of years in many parts of Asia and Africa, and they have been an essential component of the diets of many people in these regions. However, in recent years, there has been a decline in the cultivation and consumption of millets, as people have turned to other crops such as rice and wheat. This decline has led to a loss of biodiversity and a decrease in the resilience of farming systems. In this research article, we will discuss the importance of millets, their production, consumption, and development of markets, value chain, and other aspects of research and development activities on millets.

Production of Millets: Millets are grown in many countries around the world, but the majority of production occurs in India, China, and Nigeria. In India, millets are grown in the dryland areas of the country, which account for around 70% of the total area under cultivation. The major millets grown in India are pearl millet, finger millet, and sorghum. Millets are also grown in many African countries, including Mali, Burkina Faso, and Niger. The production of millets has been declining in many regions of the world due to the increasing use of modern agricultural practices and the introduction of new crops.

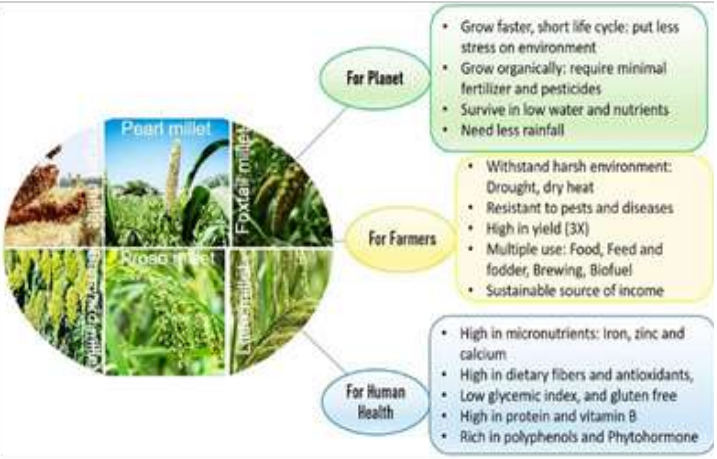

Fig. 1. Unique properties of millets for climate smart agriculture, ensuring human health, food and nutritional security

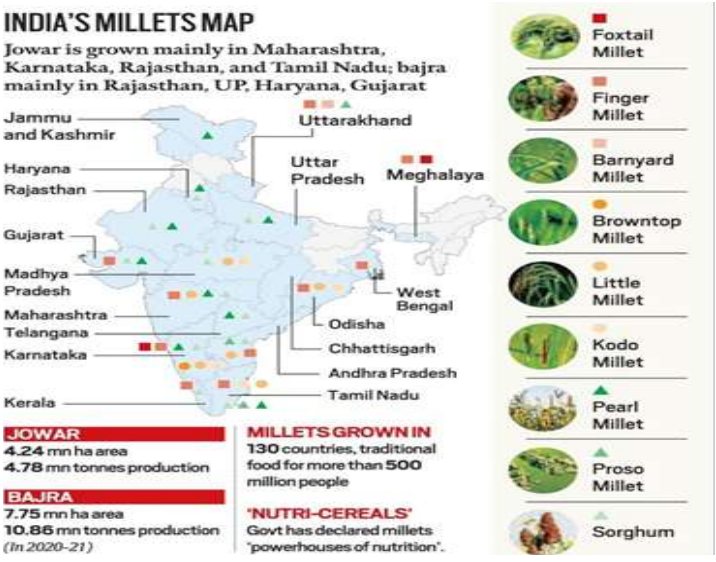

Fig. 2. India Millets Map

Table: 1. Nutritional content of various millets per 100g serving

Nutrient	Pearl Millet	Finger Millet	Foxtail Millet	Proso Millet
Energy (kcal)	378	328	351	378
Protein (g)	11.6	7.3	12.3	10.6
Fat (g)	4.2	1.3	4.3	3.1
Carbohydrates (g)	67.3	72.9	67.8	73.6
Dietary Fiber (g)	8.5	3.6	8.5	3.5
Calcium (mg)	42	344	31	15
Iron (mg)	3.9	3.9	2.8	2.1
Magnesium (mg)	114	137	126	114
Phosphorus (mg)	285	287	287	287
Potassium (mg)	300	408	246	195
Sodium (mg)	17	11	5	5
Zinc (mg)	1.7	2.7	1.4	1.7
Vitamin B1 (mg)	0.4	0.4	0.4	0.4
Vitamin B2 (mg)	0.1	0.3	0.1	0.1
Niacin (mg)	1.9	1.2	2.2	2.0
Vitamin B6 (mg)	0.3	0.3	0.3	0.3
Folate (µg)	79	44	24	85
Vitamin E (mg)	0.5	0.4	1.2	0.5
Vitamin K (µg)	0	0	0	0
Vitamin A (IU)	55	0	0	0

Source: National Institute of Nutrition, India. (2020). Nutritional composition of Indian foods

Consumption of Millets: Millets have been an important source of nutrition for people in many parts of the world. In India, millets were a staple food until the Green Revolution of the 1960s when high-yielding varieties of wheat and rice were introduced. Millets have since been largely replaced by these crops. However, there has been a growing interest in millets in recent years due to their health benefits. Millets are gluten-free, which makes them a good option for people with celiac disease or gluten intolerance. They are also low in glycemic index, which means that they do not cause a rapid increase in blood sugar levels. Millets are a good source of antioxidants, vitamins, and minerals. Decline in the consumption of milletshas led to a loss of biodiversity and a decrease in the resilience of farming systems.

Development of Market and Value Chain: The market for millets has traditionally been small and fragmented, with limited value addition and processing. However, there has been a growing interest in millets in recent years, and there are now initiatives to develop the market and value chain for millets. In India, the government has launched a millet mission to promote the cultivation, consumption, and processing of millets. The mission aims to increase the area under millet cultivation and to develop value-added products from millets. The development of a value chain for millets is essential for the promotion of millet cultivation and consumption. A value chain is a series of activities that add value to a product as it moves from the farm to the consumer. In the case of millets, the value chain includes activities such as production, processing, packaging, and marketing. The development of a value chain for millets will ensure that farmers receive a fair price for their produce, and that consumers have access to high-quality millet products. The development of a value chain for millets will also create employment opportunities in rural areas.

Table: 2 Consumption of different types of millets in India (in million tonnes)

Millet Type	2014	2015	2016	2017	2018	2019	2020	2021
Pearl Millet	5.1	4.8	3.7	3.4	3.4	3.2	3.4	3.6
Finger Millet	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Foxtail Millet	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Little Millet	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Kodo Millet	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Barnyard Millet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Millets	**6.7**	**6.5**	**5.5**	**5.0**	**4.9**	**4.8**	**5.0**	**5.2**

Source: National Institute of Nutrition, Indian Council of Medical Research

Table: 3 Millet Value Chain in India

Stage	Actors	Activities
Input supply	Seed and fertilizer suppliers	Seed production, procurement, and distribution; fertilizer supply and distribution
Production	Farmers	Land preparation, seed sowing, intercultivation, nutrient management, pest and disease management, harvesting, and threshing
Post-harvest management	Farmers, traders, and processors	Cleaning, grading, storage, and transport to markets and processing units
Processing	Processors	Dehusking, milling, and value addition
Marketing	Traders and retailers	Wholesale and retail trade in millet and millet products

Source: ICRISAT

Research and Development Activities: Research and development activities are essential for the promotion of millets. There is a need to develop new varieties of millets that are resistant to pests and diseases and can be grown in a variety of climatic conditions. There is also a need to develop new processing technologies that will enable the production of high-quality millet products. These activities include breeding programs to develop new varieties of millets that are more resistant to drought and pests, as well as efforts to improve the processing and value addition of millets.

There are also initiatives to promote the consumption of millets, including the development of recipes and the organization of millet-based food festivals.

Conclusion: Millets are an important source of nutrition that have been largely ignored by modern agriculture. However, there has been a growing interest in millets in recent years due to their health benefits. The market and value chain for millets are being developed, and there are many research and development activities focused on millets. Millets have the potential to be an important crop in the fight against hunger and malnutrition, particularly in areas that are prone to drought and climate change.

Fig. 3. Millets and its type

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Naira Nayab[1] and MD Anzer Alam[2]

[1]Ressearch scholar department of Botany, Jai Prakash University, Chhapra, Bihar,India

[2]Associate professor Ganga Singh College, Jai Prakash University, Chhapra, Bihar, India

Processing and value addition of a gluten-free millet *Eleusine coracana* L. to achieve nutritional and livelihood security

The worldwide gluten-free food demand is accelerating very rapidly due to the various health problems and mainly celiac diseases associated with the consumption of gluten containing cereals like wheat, barley, triticale and rye. Millets are the natural gluten-free diet including *Eleucine coracana* (L.), commonly known as finger millet in English and locally as mandua/ragi, is the second major small millet organically cultivated in hilly regions of Uttarakhand (Negi *et al.*, 2017). The crop is cultivated in hilly regions since millennials but its consumption and cultivation is limited only to these regions despite of its boundless health benefits. High yielding fine cereals like wheat and rice varieties which need plenty of inputs like fertilizers, pesticides etc. have displaced this crop which itself is a climate resilient crop and need not much inputs. The millet is nutritionally very rich in calcium (0.34%), carbohydrates (76.32%), protein (6-13%), fiber (18%), phytates (0.48%), minerals (2.5-3.5%) and energy (328 kcal) (Chandra *et al.*, 2016; Pandey and Kumar, 2005). Additionally, it also owns various health benefits such as it is the advisable food to the diabetic patients, and it is also used in the treatment of various ailments such as in measles, small pox, pneumonia, pleurisy and many more as shown in Fig. 1.

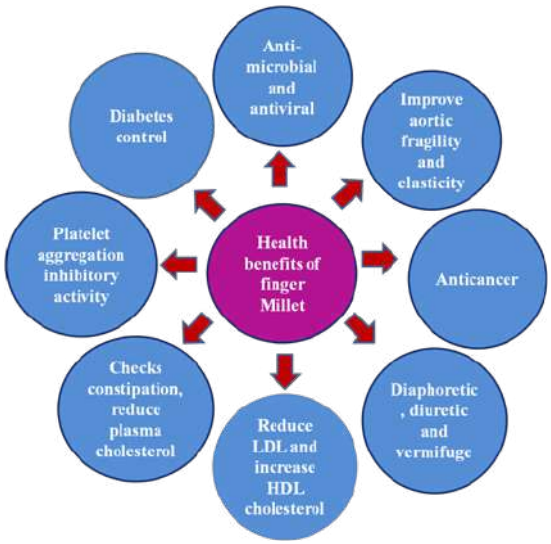

Fig. 1. Heath benefits of Finger millet

So, being nutritionally and therapeutically rich, this millet has gained the attention of researchers as well as many self-help groups (SHG) and other organizations to aware people about the nutritional value and economy associated with the various value-added products made from this millet like flour, kurkure, cookies, papad, namkeen, pasta, halwa,sweets, cake, cookies, flacks, pohaetc(Fig. 2) (Gull *et al.*, 2014) which consequently motivate people to enhance its cultivation.

Products of Finger millet

Finger Millet flour: Consumption of finger millet flour (Wheat and finger millet in the 7:3 ratio) is very familiar to mankind since ages. Addition of finger millet in the mixture reduces the gluten content in the flour thus, it is advisable to the diabetic patients. Moreover, high fibre content in finger millet also helps in eliminating the problems of constipation.

Kurkure and Noodles: Nowadays, the population is relying more on taste with nutrition so products like kurkure and noodles, very popular among every age group have created a good market. Finger millet flour in combination with other flour in a specific proportion can be used to make desired products with the help of extrusion technology.

Papad: Papad eating is enjoyed by people of all age group but people of old age got problems of diabetes, abdominal bloating and acidity so, papad made from finger millet flour mixed with green gram or other grams(Fig. 2) not only reduces these problems but also make the ingredient rich in protein, fibre, calcium and other minerals.

Fig. 2. Products of Finger millet

Puffing: The practice of puffing grains/ finger millet is very old as it enhances the taste and flavor of the millet as well as reduce the anti-nutritional factors present in it.

Idli/Dosa: The famous south Indian fermented foods i.e. idli and dosa can also be made by finger millet flour thus enhances the taste and nutritional value of the food.

Finger millet soup and other products:Finger millet is also used in soup preparation, vada, pakodaas well as in various bakery products such as in biscuits, muffins and breadand various other edibles.

With all these factsit may be concluded that the finger millet is highly nutritious crop which can be used as a source of nutrition and income generationby making these value-added products as new developmental markets. This in turn increases its consumption, cultivation and production of the milletnot only in hills but also the overall production of the country.

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Pooja Oli[1] and Shailaja Punetha[2] (*shailupunetha@gmail.com*)
GBPNIHE, Kosi-Katarmal, Almora, Uttarakhand, India

Nutraceutical values and diversity of millets in Indian Himalayan Region

The United Nation's general assembly at its 75th session in march 2021 declared year 2023 will be celebrated as the international year of millets, under the governance of India. India produced 120 lakh tonnes of the total 304.8 lakh tonnes millets globally in 2022. The worldwide three countries namely India (40%), Niger (11%) and China (9%) are collectively produced more than 50% of the total millets (1). The year 2023 is an opportunity to generate knowledge, promote millets consumption, sustainable market opportunities for producers and consumers, policy preparation and planning, suitability cultivation, nutraceuticals value and their health benefits. The international year of millets aims to contribute in the sustainable development goals of UN agenda 2030 by targeting including SDG 2 (Zero Hunger), SDG 3 (Good health and well-being), SDG 8 (Decent work and economic growth), SDG 12 (Responsible consumption and production), SDG 13 (Climate action) and SDG 15 (Life on land). The millets grow in marginal soil (rocky, sandy or shallow), and having qualities like drought & disease resistant, require less water, least care and has been part of cultivation and food, fodder and beverages in the Indian Himalayan Region since long time. The millets are also known as store house of nutrients including protein, fat, minerals, dietary fiber, soluble/insoluble dietary fiber and various vitamins similar to carotenoids, thiamine, riboflavin and niacin. The millets are also rich in minerals including calcium, phosphorus, iron, magnesium, sodium, potassium, copper, zinc etc. therefore, millet production is likely to be increased across the globe including India. The climate scientists are optimistic that millets can be a climate smart option as future food and agricultural practices. The Bihar and Assam states have highest production and consumption of small millets whereas Madhya Pradesh has highest area production of small millets (32.4%) followed by Uttarakhand, Maharashtra Chhattisgarh, Tamil Nadu and Gujarat. There are eight types of millets are found in Indian Himalaya Region.

Table: 1. Nutraceuticals value and diversity of Millets in Indian Himalayan Region

Type of Millets	Health Benefits	Diversity in IHR	Nutritional / Minerals/ Vitamins values per 100g
Barnyard millet (*Echinochloa frumentacea*)	Promote immunity, control diabetes mellitus, blood pressure, cholesterol, improve skin and hair health, cure gastrointestinal disorders, helps in regular bowel movements, eliminates constipation, acidity, bloating, and stomach cramps	Assam, Uttarakhand	Protein 10.5g, Fat 3.6g, Crude fibre 6.6mg, Minerals 2.0g, Carbohydrates 68.8g, Calorific value 398.0g, Dietary fibre 12.6g, Soluble dietary fibre 4.2g, Insoluble dietary fibre 8.4g, Phosphorus 281mg, Iron 5.0mg, Magnesium83mg Calcium 19mg
Finger millet (*Eleusine Coracana)*	Strengthening bones for growing children and aging people, help in smooth neuromuscular function, improve kidneys & heart functioning, weight loss, improve skin and hair health, Prevents diabetes and colon cancer	Arunachal Pradesh, Himachal Pradesh, Meghalaya, Nagaland, Sikkim, Uttarakhand	Calcium 364mg, Protein 7.2 g, Magnesium 146mg, Iron 4.6mg, Zinc 2.5mg, Dietary fiber 11.2 gm
Foxtail millet (*Setaria italic*)	Maintaining a healthy heart, smooth functioning of the nervous system, improve skin and hair health, help in reduce muscular spasms and eases out restless syndrome, help to manage diabetes, hypertension/ high blood pressure, colorectal cancer, fungal infections	Arunachal Pradesh, Assam, Jammu and Kashmir, Himachal Pradesh, Meghalaya, Uttarakhand	Energy 331kCal, Protein 12.3g, Dietary fibre 8g, Fat 4.3g, Phosphorus 290mg, Potassium 250mg, Magnesium 81mg, Calcium 31mg, Folic acid 15mg, Sodium 4.6mg, Niacin 3.2mg, Iron 2.8mg, Zinc 2.4mg, Vitamin A 32mg, Vitamin E 31mg
Kodo millet (*Paspalum scobiculatum*)	Reduced levels of low-density lipoprotein, risk of cancers, reduced joint pain, wrinkles and manage bacterial infections, type-2 diabetes, weight loss, improve skin and hair health	Himachal Pradesh	Carbohydrate 59.2g, Protein 10.6g, Fibre 10.2g, Fats 4.2g, Phosphorus 188mg, Potassium 07.8mg, Calcium 27.0mg, Sodium 3.48mg, Zinc 1.58mg, Iron 0.5mg, Folate 33.06mcg, Vitamin K 0.5mcg, Vitamin B2 0.09mg, Vitamin B1 0.18mg, Vitamin B5 0.28mg, Vitamin B3 2.0mg
Little millet (*Panicum miliare*)	Reduce diabetes, cardiovascular diseases, cataract, cancer, weightless, inflammation, gastrointestinal problems and delay ageing, asthma, reduced levels of low-density lipoprotein, manage bacterial infections, manage type-2 diabetes, reduced risk of cancers, relief from joint pain, help in weight loss, reducing wrinkles	Himachal Pradesh	Calories 378KCal, Protein 7.7g Fat 4.0g, Carbohydrates 67g, Fiber 7.6g, Calcium 17mg, Iron 9.3mg, Magnesium 119mg, Phosphorus 283mg, Potassium 207mg, Sodium 5mg, Zinc 1.7mg
Pearl millet (*Pennisetum typhoides*)	Reduce diabetic, cholesterol, acidity, bones stronger and promote healthy heart	Mizoram, West Bengal hill	Protein 10.96gm, Dietary fibres 11.49gm, Fat contents 5.43gm, Carbohydrates 61.78gm, Energy 1456KJ
Proso millet (*Panicum miliaceum*)	Reduces heart attack, strokes and atherosclerosis, type-2 diabetes, prevent breast cancer, remove bad cholesterol, nervous anomalies and memory diseases such as dementia and Alzheimer's, decrease	Jammu and Kashmir, Himachal Pradesh	Energy 309Kcal, Protein 8.30g, Carbohydrate 65.90g, Crude Fibre 9.00mg, Calcium 27.00mg, Iron 0.50mg
Sorghum millet (*Sorghum bicolor*)	Reduce the risk of CVD, colon cancer, type 2 diabetes, maintaining a healthy digestive system, weight loss cell regeneration	Mizoram	Energy 349Kcal, Protein 10.4g, Carbohydrate 2.6g, CrudeFibre 1.2g, Calcium 42mg, Iron 8.0mg

Source: https://apeda.gov.in.

References

https://www. fao.org.

Mahesha Nand (*maheshlyf87@gmail.com*), Mahendra Singh Lodhi, Kamal Kishor Tamta and Vijay Singh Bisht
GBPNIHE, Kosi-Katarmal, Almora, Uttarakhand, India

उगल/कुट्टू एक बहुउपयोगी एवं उपेक्षित धान्य रूप फसलें हैं जिसकी खेती खरीफ ऋतु में मध्य एवं उच्च हिमालयी क्षेत्रों में सुगमता से की जा सकती है। जिसकी दो मुख्य जातियां उगल तथा फाफर *फाइगोपाइरम इस्कुलेंटम* व *फाइगोपाइरम टटेरीकम* फसल के रूप में उगाई जाती हैं। उगल निचली एवं मध्यम ऊँचाई के लिए तथा फाफर अधिक ऊँचाई वाले क्षेत्रों के लिए उपयुक्त है। ऊँचे पहाड़ी क्षेत्रों में इसको खाद्यान्न के रूप में प्रयोग किया जाता है। सामान्य रूप से अम्लीय एवं बंजर भूमि में इसकी खेती की जाती है। यह फसल मृदा आच्छादन व भूमि क्षरण की रोकथाम के लिये उपयुक्त पाई गई है तथा इससे हरी खाद भी बनायी जाती है। उगल/कुट्टू की खेती वि वर्षभर की जाती है परन्तु चीन, दक्षिण कोरिया, जापान, यूरोप तथा कनाडा में इसकी खेती वृहद स्तर पर की जाती है। भारतवर्ष के उत्तर – पश्चिमी हिमालयी क्षेत्र में उगल एवं कुट्टू की खेती अधिक प्रचलित है।

Ikpfyr uke	LFkkuh; uke	okuLifrd uke	vxzsth uke	mxk;s tkus oky {ks=
कुट्टू	उगल	*फाइगोपाइरम इस्कुलेंटम*	बकव्हीट	उत्तराखण्ड, हिमाचल प्रदेश, जम्मू क मीर, मेघालय, सिक्किम, मणिपुर, आसाम इत्यादि राज्य

कृषकों को यदि समुचित बाजार व्यवस्था मिल जाय तो यह फसल उनके लिए वरदान साबित हो सकती है। कुट्टू का बीज भूरा, काला, हल्का लाल सा दिखाई देता है। तीन धारों वाला इसका आगे से नुकीला होता है। फसल के वानस्पतिक विकास के साथ – साथ इसकी जड़ें भी मृदा में तेजी से फैलती है। अतः यह फसल मृदा क्षरण रोकने में भी सहायक होती है।

mUur'khy izkfr;k

ih0 vkj0 ch0 1% यह प्रजाति गो0ब0पन्त कृषि एवं प्रौ0 विश्वविद्यालय, के वानिकी एवं पर्वतीय कृषि महाविद्यालय, रानीचौरी द्वारा वर्ष 1997 में विकसित की गई है। इसकी उपज क्षमता 18–20 कुन्तल प्रति हैक्टेयर है तथा यह प्रजाति उत्तराखण्ड, हिमाचल प्रदेश राज्य के पर्वतीय क्षेत्र के लिए अनुमोदित है। यह फसल 100–108 दिन में पककर तैयार हो जाती है।

fgefi;k% यह प्रजाति राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो शिमला द्व ारा वर्ष 1990 में विकसित की गई है। इसकी उपज क्षमता 20 कुन्तल प्रति हैक्टेयर है तथा यह प्रजाति उत्तराखण्ड, हिमाचल प्रदेश राज्य के पर्वतीय क्षेत्र के लिए अनुमोदित है। यह फसल 110–120 दिन में पककर तैयार हो जाती है।

oh0 ,y0 7% यह प्रजाति विवेकानन्द पर्वतीय कृषि अनुसंधान संस्थान अल्मोडा द्वारा वर्ष 1991 में विकसित की गई है। इसकी उपज क्षमता 10 कुन्तल प्रति हैक्टेयर है तथा यह प्रजाति उत्तराखण्ड, हिमाचल प्रदेश राज्य के पर्वतीय क्षेत्र के लिए अनुमोदित है। यह फसल 70–80 दिन में पककर तैयार हो जाती है।

f'keyk ch 1% यह प्रजाति भी राष्ट्रीय पादप आनुवंशिक संसादन ब्यूरो शिमला द्वारा विकसित की गई है। इसकी उपज क्षमता 15 कुन्तल प्रति हैक्टेयर है तथा यह प्रजाति उत्तराखण्ड, हिमाचल प्रदेश राज्य के पर्वतीय क्षेत्र के लिए अनुमोदित है। यह फसल 100–105 दिन में पककर तैयार हो जाती है।

उगल/कुट्टू से अधिक उत्पादन प्राप्त करने हेतु उन्नत सस्य क्रियायें निम्न लिखित हैं –

Hkfe% इसकी खेती सभी तरह की मिट्टियों में की जा सकती है। यद्यपि इसके लिए मध्यम उपजाऊ, हल्की भूमि उपयुक्त होती है। तथापि यह फसल अम्लीय, पथरीली मिट्टी एवं कंकड़ पत्थर के ढेर में भी उगने की क्षमता रखता है। आर्द्र एवं ठण्डी जलवायु कुट्टू के लिए अच्छी होती है।

cokbZ dk le;% कुट्टू/उगल की बुवाई पर्वतीय क्षेत्रों में ऊँचाई पर निर्भर करती है। ऊँचे पर्वतीय क्षेत्रों (1500–2400 मी0) में मई का द्वितीय पखवाड़ा तथा मध्यम व निचले पर्वतीय क्षेत्रों में जून का प्रथम पखवाड़ा उगल की बुवाई का उपयुक्त समय होता है।

cokbZ fof/k% कुट्टू/उगल के बीज को सामान्यतः छिटक कर बोया जाता है। लेकिन शोधों से प्राप्त परिणाम से यह दर्शाते हैं कि अगर उगल/कुट्टू की बीजाई लाईन में की जाय तो अधिक उत्पादन प्राप्त होता है। लाईन में बुवाई के लिए लाईन से लाईन की दूरी 30 सेमी तथा पौध से पौध की दूरी 10 से.मी. रखनी चाहिए।

cht nj% लाईन से बुवाई के लिए 25 किग्रा प्रति हैक्टेयर और छिटकवॉ विधि से बुवाई करने के लिए 30 किग्रा बीज प्रति हैक्टेयर की आवश्यकता होती है।

mipkj% बुवाई से पूर्व बीज को 10–15 मिनट तक 10 ग्राम एजेटोवैक्टर प्रति किग्रा बीज की दर से उपचारित करने पर अधिक उपज प्राप्त होती है।

Qly izcU/k% उगल/कुट्टू मुख्यतः शुद्ध फसल के रूप में उगाई जाती है। उगल/कुट्टू को सह फसल खेती हेतु मक्का के साथ उगा सकते है उगल/कुट्टू आधारित कुछ फसल चक्र इस प्रकार है।

उगल/कुट्टू – मटर (1 वर्ष)
उगल/कुट्टू – गेहूँ (1 वर्ष)
उगल/कुट्टू – मसूर (1 वर्ष)
उगल/कुट्टू – जौ/जई (1 वर्ष)

lkj.kh 1&ik"kd rRoksa dh fgkt l dVV] xgk ,oa pkoy dh r;qyuk

ik"kd rRo	dVV@ mxy	xgk	Pkkoy
प्रोटीन (ग्रा./100 ग्रा.)	12.0	11.8	6.8
वसा (ग्रा./100 ग्रा.)	2.4	1.5	0.5
ऊर्जा (किलो कैलोरी)	355	346	345
रेशा (ग्रा./100 ग्रा.)	10.3	1.2	0.2
खनिज लवण (ग्रा./100 ग्रा.)	2.9	1.5	0.7
कैल्शियम (मि.ग्रा./100 ग्रा.)	114	41	10
लोहा (मि.ग्रा./100 ग्रा.)	13.2	3.5	1.8
लाईसिन (ग्रा./100 ग्रा. प्रोटीन)	6.2	2.6	3.7
मिथायोनीन (ग्रा./100 ग्रा. प्रोटीन)	1.6	1.5	2.4
सिस्टीन (ग्रा./100 ग्रा. प्रोटीन)	1.6	2.2	1.4
आईसोल्युसिन (ग्रा./100 ग्रा. प्रोटीन)	3.7	3.3	3.9

ik"kd rRo izcU/ku% जैविक खेती के अन्तर्गत इस फसल से अधिक उत्पादन प्राप्त करने हेतु 8 टन प्रति हैक्टेयर गोबर की सड़ी खाद अथवा 4 टन वर्मी कम्पोस्ट प्रति हैक्टेयर की दर से प्रयोग करना चाहिए। गोबर की सड़ी खाद को बुवाई से 15–20 दिन पूर्व खेत में छिटक कर जुताई कर देनी चाहिए। कुट्टू/उगल की फसल मृदा से पोषक तत्वों का

प्रबन्धन पर विशेष ध्यान देने की आवश्यकता होती है। उगल/कुट्टू की खेती जैविक तथा रासायनिक दोनों प्रकार से की जाती है। अधिक उत्पादन प्राप्त करने के लिए रासायनिक रूप से 40 किग्रा नत्रजन तथा 20 किग्रा फास्फोरस प्रति हैक्टैयर की अनुशंसा की जाती है। जिसमें नत्रजन की आधी मात्रा तथा फास्फोरस की पूरी मात्रा बुवाई के समय खेत में मिला देना चाहिए । भोश आधी मात्रा बुवाई के 40–50 दिन बाद खड़ी फसल में निराई – गुड़ाई के उपरान्त प्रयोग करना चाहिए तथा इस मात्रा के प्रयोग से लगभग 15 (14.7) कुन्तल दाना प्रति हैक्टेयर उत्पादन प्राप्त हुआ है।

fojyhdj.k ,oa [kjirkj fu;a=.k% उगल/कुट्टू के अतिरिक्त पौधों की छंटाई कर पौधों से पौधों की दूरी लगभग 10 सेमी कर देना चाहिए। फसल की शुरू की अवस्था में खरपतवार अधिक नुकसान पहुँचाते हैं। इसलिये खरपतवार नियन्त्रण के लिए 1 या 2 गुडाई 20–40 दिन की अवधि में करना आवश्यक है अर्थात फसल को प्रथम 30 से 40 दिनों तक खरपतवार मुक्त रखना चाहिए। बुवाई के 15–20 दिन बाद एक निराई हैण्ड हो से कर देनी चाहिए। अधिक खरपतवार होने की दशा में दूसरी निराई पहली निराई के 20 दिन बाद करनी चाहिए। समय तथा श्रम की बचत के लिए यान्त्रिक निराई यन्त्र /हैण्ड हो का प्रयोग किया जाता है। एलाक्लोर के 1.5 कि.ग्रा. प्रति हैक्टेयर की दर से 800 लीटर पानी में मिलाकर छिड़काव करने से खरपतवारों का नियंत्रण होता है।

Qly lqj{kk% उगल/कुट्टू की फसल में कीट एवं बीमारियों का प्रकोप कम ही होता है। किन्तु रोग आने पर नीम के तेल का प्रयोग करना चाहिए तथा रोगी पोधे को उखाड कर अलग कर देना चाहिए।

mxy@dqVw l cuus oky 0;atu@mRikn% कुट्टू के मुलायम तनों एवं हरी पत्तों को साग एवं सूप के रूप में प्रयोग में लाया जाता है। अधिकांशतः कुट्टू की पत्तियों को रामदाना, बथुवा की पत्तियों के साथ मिलाकर साग बनाया जाता है। कुट्टू के आटा व्रत आदि में विशेष रूप से प्रयोग में लाया जाता है। इसके दानों में लाइसिन की मात्रा अधिक होने के कारण धान एवं गेहूँ की तुलना में बेहतर माना जाता है। कुट्टू के आटा को गेहूँ धान एवं मक्के के आटे के साथ मिलाकर नूडल्स, बिस्कुट, फैन, केक आदि बनाये जाते हैं। इसके चावल को भात के रूप में भी प्रयोग में लाया जाता है। कुट्टू से बने हुये नूडल्स की मॉग अपनी गुणवत्ता के कारण दक्षिण–पूर्वी एशिया में अधिक है। कुट्टू के फूलों से तैयार शहद गुणवत्ता की दृष्टि से उच्च कोटि का माना जाता है।

mxy@dqVw dk vk"k/kh; x.k% कुट्टू/उगल से रयूटिन नाम की एक महत्वपूर्ण औषधि भी प्राप्त होती है जो कि उच्च रक्त चाप से ग्रसित रोगियों के लाभदायक पाई गई है। वर्तमान समय में स्वास्थ्य की दृष्टि से कुट्टू के आटे का महत्व दिन प्रतिदिन बढ़ता जा रहा है। इसमे एन्टीआक्सीडेन्ट अधिक होने के कारण कैंसर की बीमारी के प्रति अवरोधी माना जाता है। यह पित्त की पथरी को नहीं बनने देता है तथा रक्त में कोलेस्ट्राल की मात्रा को कम करता है। इस तरह किसान भाई विशेषकर जो पर्वतीय कृषक बंधु है उगल की वैज्ञानिक विधि से खेती करके अधिक से अधिक उपज प्राप्त कर उसे उचित मूल्य पर बाजार में बेचकर अधिक आय अर्जन कर परिवार की आय में वृद्धि करने के साथ–साथ अपने परिवार को स्वस्थ रखने में मदद करे।

vuhrk f=ouh[1] v:.k HkVV[2] ,oa fxjh'k frokjh[3]
श्री गुरू राम राय विश्वविद्यालय, देहरादून, उत्तराखण्ड
जैव प्रोद्योगिकी विभाग गो.ब.पंत इन्सटीट्यूट ऑफ इंजीनियरिंग एण्ड टैक्नोलॉजी घुरदौड़ी, पौड़ी गढ़वाल, उत्तराखण्ड, भारत

जब हम मिलेट्स के बारे में बात करते हैं तो हमें यह जान लेना अवश्यक हो जाता है कि मिलेट्स एक ऐसा पोषक अनाज है जो हमारे भोजन का अहम हिस्सा तो है ही साथ ही इसके पोषक तत्व भी हमारे जीवन के लिए बहुत अवश्यकीय हैं। आज खाद्य उत्पादन में कृषकों को जिन–जिन समस्याओं का सामना करना पढ़ रहा है उन्हें ध्यान में रखते हुए उन समस्याओं के निवारण हेतु प्रस्तावों के माध्यम से मिलेट्स के उत्पादन पर विशेष ध्यान देने की बात कही गयी है। मिलेट्स कई पोषक तत्वों के युक्त होने के कारण स्वास्थय सम्बन्धी गुणवत्ता पर भी खरा उतरा है। कहने का आशय यह हुआ कि मिलेट्स उत्पादन हेतु व्यापक जागरूकता, गहन अनुसन्धान के साथ ही विशेष प्रोत्साहन दिए जाने की बात की जाए।

ifjp; ,oa tkudkjh% मिलेट्स पोषक तत्वों का एक बहुत समृद्ध स्रोत है। आज से ५०–६० साल पहले मिलेट्स हमारे भोजन का अहम हिस्सा थे, परन्तु हरित क्रांति के दौरान गेहूँ और चावल को प्राथमिकता दी गयी जिसकी वजह से इस की मांग में कमी आयी, मिलेट्स की कमी होने का एक मुख्य कारण यह भी है कि मिलेट्स को हम गरीबों का भोजन भी मानते हैं। दुनिया में खाद्य संकट, बढ़ती पानी की कमी और जलवायु परिवर्तन के कारण अनाज के उत्पादन में किसानों को कठिनाइयों का सामना करना पड़ रहा है, जिसके निवारण हेतु हमारे प्रधानमंत्री श्री नरेंद्र मोदी जी ने मिलेट्स की गुणवत्ता के बारे में लोगों को जागरूक किया। भारत सरकार ने इसके लिए संयुक्त राष्ट्र को प्रस्ताव दिया था, भारत के प्रस्ताव को ७२ देशों और संयुक्त राष्ट्र का समर्थन प्राप्त था। संयुक्त राष्ट्र महासभा (यूनजीए) ने २०२३ को अंतर्राष्ट्रीय मिलेट्स वर्ष घोषित किया । अब भारत सरकार ने फैसला किया है कि भारतीय मिलेट्स के व्यंजनों और मूल्य वर्धित उत्पादों को विश्व स्तर तक पहुंचना है (प्लवड)। मिलेट्स का उत्पादन मुख्य रूप से भारत, दक्षिण अफ्रीका, अफ्रीका, नाइजीरिया और चीन में होता है। वर्ष २०२२ में भारत दुनिया में मिलेट्स का सबसे बड़ा उत्पादक है। अलग–अलग मिलेट्स में पोषक तत्वों की मात्रा अलग–अलग होती है जो कि निम्नलिखित तालिका में प्रदर्शित की गई है।

मिलेट्स एक ग्लूटेन फ्री पदार्थ है जो कि स्वास्थ्य सम्बंधित समस्याओं के लिए लाभदायक है और इनमे विटामिन बी पाया जाता है जो मधुमेह रोग के लिए लाभदायक होता है। मिलेट्स के इन्ही फायदों को ध्यान में रखते हुए सरकार व कृषि संस्थान इसके उत्पादन व दैनिक आहार पर जोर दे रहे हैं। सरकार, राष्ट्रीय खाद्य सुरक्षा मिशन (ऐनएफऐसएम) पर उपमिशन के अंतर्गत पोषक अनाज प्रदर्शन और प्रशिक्षण के माध्यम से रागी, ज्वार, बाजरा और छोटे मिलेट जैसे पोषक अनाज (मिलेट्स) के लिए किसानों के बीच जागरूकता पैदा कर रही है। सरकार और कृषि मंत्रालय द्वारा इस प्रस्ताव के फलस्वरूप मिलेट्स के उत्पादन से भारत में रोजगार के साधन आएंगे और हमारी देश की आर्थिक स्थिति में भी सुधार आएगा। भारत के विभिन्न राज्यों में मिलेट्स की खेती होती है। राज्यों की सूची के अनुसार मिलेट्स की खेती सर्वाधिक राज स्थान राज्य में होती है जबकि उत्तरप्रदेश, गुजरात, उत्तराखंड, मध्यप्रदेश, महाराष्ट्र राज्यों में मिलेट्स सामान्य मात्रा में पाया जाता है। इसके अलावा तमिलनाडु और कर्नाटक राज्य में मिलेट्स का उत्पादन काफी कम है। वर्षवार भारत में मिलेट्स का उत्पादन चित्र १ (IYoM) में प्रदर्शित किया गया है। चित्र २ (APEDA) में भारत में राज्य के अनुसार मिलेट्स का उत्पादन दर्शाया गया है।

मिलेट्स उत्पादन हेतु गेहूँ और चावल की तुलना में ७०% कम पानी की आवश्यकता होती है। इनकी खेती की अवधि भी अन्य की तुलना में आधी होती है। इनके उत्पादन में४०% कम ऊर्जा की आवश्यकता होती है। इनके उत्पादन के लिए जैव और रासायनिक उर्वरक की आवश्यकता भी नहीं पड़ती। इन्हें लंबे समय तक संग्रहीत किया जा सकता है। ये

rkfydk% पोषक तत्वों की मात्रा प्रति १०० ग्राम में (Deshpande *at el.*, 2015)

feyVl	çkVhu ¼xke½	Qkbcj ¼xke½	feujYl ¼xke½	vk;ju ¼feyhxke½	dfY'k;e ¼feyhxke½	dkcksgkbMsVl ¼xke½	Q,LQkjl ¼feyhxke½
fQxjfeyV	7-5-11-7	3-6	2-7	3-6-6-8	344-515	65-5	283
cku;kMfeyV	6-2	9-8	4-4	15-2	11	65-5	280
Q,DlVyfeyV	11-2	6-7	3-3	2-8	31	63-2	-
iyfeyV	8-5-15-1	2-6-4-0	1-6-2-4	70-180	10-80	58-70	450-990
dknkfeyV	8-3	9-0	2-6	0-5	27	65-9	188
fyfVyfeyV	7-7	7-6	4-5	9-3	17	67	220

पर्यावरण हितैषी हैं और मिलेट्स की खेती के लिए कृत्रिम वातावरण की आवश्यकता नहीं पड़ती। मिलेट्स कठोर जलवायु परिस्थितियों में जीवित रह सकते हैं और ये भोजन की कमी का समाधान भी करते हैं। ये एक मात्र ऐसी फसलें होती हैं जिन्हें शुष्क ऋतु में काटा जाता है। मिलेट्स खाद्य आपदा की चपेट में आने वाली आबादी के लिए एक महत्वपूर्ण खाद्य स्रोत हो सकता है और अन्य अनाजों पर हमारी निर्भरता को कम कर सकता है। मिलेट्स की आनुवंशिक विविधता,चिकित्सा एवं औषधि जैसे क्षेत्रों को द्रिष्टिगत रखते हुए मिलेट्स के कई विविध और नवीन प्रयोगों के लिए प्रोत्साहन देने का कार्य किया गया है। इसीलिए नवोन्मेषी रूप से उपयोग किए जाने वाले मिलेट्स क्षेत्रीय और अंतर्राष्ट्रीय व्यापार के लिए और भी अधिक व्यापार अवसर प्रदान करते हैं। अनुसंधान के अनुसार मिलेट्स में हम कुछ सूक्ष्मजीवों का उपयोग करके पोषक तत्वों की मात्रा को बड़ा सकते हैं। मिलेट्स उत्पादन में सूक्ष्मजीव जड़ों के माध्यम से पौधे को लाभ देते हैं और पोषक तत्वों की मात्रा में बढ़ोतरी करते हैं, लाभ की द्रिष्टि से हम जड़ों से उनके खनिजों और पोषण तत्वों को अलग करते हैं इसके अलावा मानव एवं जीवों की उन्नति व तरक्की के लिए अनुसंधान करते हैं, साथ ही पर्यावरण को अनुकूल बनाए रखने के लिए हम जैव उर्वरक का उपयोग करते हैं जो मिट्टी की उर्वरता को बढ़ाता है।

LokF; fd fnf"V l feyVl d Qk;n% मिलेट्स जहाँ वजन घटाने में सहायता करता है, वहीं रक्त शर्करा के स्तर को भी कम रखता है। मिलेट्स रोग प्रतिरोधक क्षमता को बढ़ाता है। मिलेट्स हृदय संबंधी जोखिम को कम करता है। मिलेट्स अस्थमा को रोकता है। आयरन व विटामिन की कमी को मिलेट्स के सेवन से प्रभावी रूप से निपटा जा सकता है। मिलेट्स अन्य कार्बोहाइड्रेट की तुलना में अधिक समय तक पोषित रखता है। मिलेट के सेवन से पाचन क्रिया सुचारु रूप से चलती है और इसके सेवन से पेट सम्बन्धी विकार व समस्याएं भी कम होती है। मिलेट्स में आवश्यक व सात तत्व होते हैं, जो हमारे शरीर को संतुलित वसा प्रदान करते हैं एवं अतिरिक्त वसा भंडारण को रोकते हैं। इसके अलावा मिलेट्स उच्च कोलेस्ट्रॉल और अन्य हृदय संबंधी शिकायतों के जोखिम को प्रभावी रूप से कम करते हैं।

feyVl d dN e[; mi;kx g%

बिस्कुट, कूकीज और किण्वन उत्पादन।

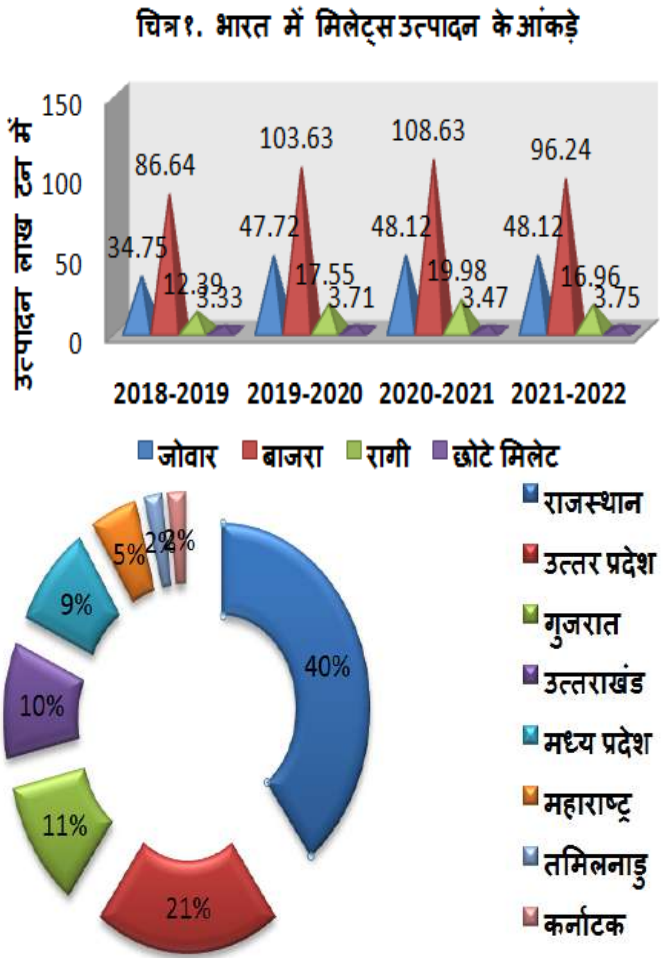
न्यूट्रास्यूटिकल उत्पादन।

मधुमेह सम्बंधित रोग में इसका प्रयोग होता है।

भोज्य प्रदार्थ– मल्टीग्रेन पापड़, चीला, रागी इंस्टेंट ड्रिंक, इडली, मल्टीग्रेनब्रेड, रागीपापड़, मल्टीग्रेन हलवा, मल्टीग्रेन पास्ता और रागी मुरुक्कू मिक्स आदि।

fu"d"k% उक्त लेख में दी गई महत्वपूर्ण जानकारियों के आधार पर निष्कर्ष रूप में यह कहा जा सकता है कि मिलेट्स में प्रोटीन एवं कार्बोहाइड्रेट्स प्रचुर मात्रा में पाया जाता है इसी कारण हमें मिलेट्स उत्पादन को बढ़ावा देने हेतु अथक प्रयास किये जाने की आवश्यकता है ताकि बढ़ती हुई जनसँख्या को ध्यान में रखते हुए मिलेट्स अधिकांश गरीबों एवं किसानों के बेहतर जीवन–यापन का सहारा बन सके।

चित्र१. भारत में मिलेट्स उत्पादन के आंकड़े



fp=- 2- वर्ष 2021–22 में राज्यवार मिलेट उत्पादन

lUnHk%

इंटरनेशन लईयर ऑफ मिलेट्स (प्लवड)–२०२३, मिनिस्ट्री ऑफ एग्रीकल्चर एंड फार्मर्स वेलफेयर, नेशनल कांफ्रेंस ऑन खरीफ कैंपेन, २०२२,१६ अप्रैल, २०२२.

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lykuh dqoj[1] vkfnR; tk'kh[2] ,oa ugk ikM[1]

[1]डिपार्टमेंट ऑफ़ बायो टेक्नो लॉजी, ग्राफ़िक एरा डीम्ड टू बी यूनिवर्सिटी, देहरादून, उत्तराखंडए भारत

[2]डिपार्टमेंट ऑफ़ कंप्यूटर साइंस एंड इंजीनियरिंग, ग्राफ़िकएरा डीम्ड टू बी यूनिवर्सिटी, देहरादून, उत्तराखंड, भारत