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Review Article

Millets Cultivation in Non-Conventional Zone- Practices, Possibilities and Prospects

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Abstract

The millets are highlighted in recent years due to their climate resilient nature, nutritional superiority over major cereals and policy interventions; considering this, the potential of millets to grow in organic production system at commercial scale in new or non-conventional area needs attention. The Meghalaya is known for diversified soil, land topography, climatic condition and crop diversity. The production systems are dominated by traditional knowledge and practice with organic production system which can be utilized for searching new interventions in millet cultivation under organic production system at commercial level. This review summarise the prospects of millets with special reference to their nutritional and ecological significance, recommended production practices and interventions for promotion of millet cultivation under organic production system with special reference to Meghalaya. The varietal evaluation following recommendation given at national level, exploring the possibility of organic seed production, identification of economic viability of different millets in non-conventional area and upscaling of processing and value addition of millets products need be to given importance for successful cultivation of millets in new non-conventional area.

Keywords: Finger Millet; Meghalaya; Organic Farming; Pearl Millet

Introduction

The North East Hill (NEH) region is bestowed by large natural and biodiversity and spread from Arunachal Pradesh in extreme east, Sikkim in North and Meghalaya in west and south and surrounding Assam. The variations in agro-climatic conditions are classified in to weather variation, soil and topographical variation and agricultural crop and practices diversity. The variations are expressed mainly in terms of rainfall distribution (quantity and distribution) and cloudiness, temperature and relative humidity variation; while changes in topography, variation in soil organic carbon, susceptibility to erosion and soil depth are commonly used parameters for defining the soil parameter variations [1-3]. The diversity of crops grown can be realized from arable crops, orchard and vegetables and agro-forestry/forestry crops grown in single state i.e., Meghalaya [4-5]. The practices such as shifting cultivation, bun cultivation and zebu cultivation, rice lowland paddies, animal component (Pig, Poultry, Yak, etc.), broom grass cultivation, different types of land configuration (such as raised and sunken bed, terracing, permanent raised beds, etc.) and organic production system are traditional agricultural practices in NEH region; while introduction of maize species diversity, growing of cole crops after rice harvest, exploring different intercropping system (french bean+maize, soybean+rice) [6-7], increasing rearing of exotic milch animal and allied enterprises (such as sericulture, bee keeping, etc.) are the conventional practices in NEH region [8-9]. Considering this considerable diversity in NEH region, the introduction and testing of new crops and identifying the potential niche for the organic production system for these crops and seed production of these crops will be a potential area which need to be explored. Among the group of crops, millets are expected to have highest potential due to their high capacity to stand diverse agro-climatic situation and soil regimes. Besides that, millets will be an important source of nutrition considering their richness in different minerals [10,11].

The UN general assembly declared 2023 as "International Year of Millets (IYM-2023)" with theme "Rich in Heritage, Full in Potential"; while Indian Government declared 2018 as "Year of Millets". Under the edges of IYM-2023, Government of India (GoI) promotes the Millets production, processing and consumption at different forum. The seven themes put forwards for millet promotion by GoI are "enhancement in production/productivity, nutrition and health benefits; value-addition, processing and recipe development; Entrepreneurship/start up and collective development; awareness creation- branding, lebelling and promotion; International outreach; policy interventions for mainstreaming. The Food and Agricultural Organization also take IYM 2023 as important opportunity to emphasis the promotion of millets with aims at a) increasing awareness about multiple benefits of millets, b) strengthen science-policy interaction, empower stakeholders to take action and c) building partnership with while strengthening existing one for IYM-2023. Considering the agroclimatic and nutritional potential of millets, their exploration for NEH region is important opportunity on the climate changes induced crop cultivation practices.

The climate change induces changes in the crop cultivation practices and crop growing zones which expected to be again widen in future. In such condition mitigation alone will not be sufficient to produce enough provisional services and finding the alternatives in time space dimension for growing crop is at most important. Such attempts to identify the potential adaptation strategy are identified as climate resilient agriculture and off late environmental responsive agriculture. The millets are considered as climate resilient crops due to their capacity to grow in harsh environment, low soil fertility and undulating topography [12,13]. The millets are also more nutritious than routine cereal crops and are cost effective. Considering these characteristics of millets, the research on these crops in new environment will be valid research interventions with economic gain expected with policy support of IYM-2023. With this conducive policy environment, research need of identification of new niche for crops under research theme of shifting crop cultivation zone [14] and potential of organic seed production of NEH region, interventions in crop production system in NHE region in general and Meghalaya in particular through millet cultivation is achievable target. It has scientific and policy recommendation outcomes (through visits of farmers for promotion of millets); while economic outturns need to be tested through calculation of economics at research field.

Millets- an introduction

The millet cultivations in India defined in terms of number of millets and their comparative significance, spread in terms of area, ecological suitability, nutritional importance, response to input and management practices, processing and value addition, research and policy interventions. Indian is growing 4 millets crops on accountable area (Sorghum (*Sorghum bicolor* L. Moench), Pearl millet (*Pennisetum Glaucum*), Barley (*Hordeum vulgare l.*) and Finger millet (*Eleusine Coracana* (L.) Gaertn.); while other millet crops such as Foxtail millet (*Setaria italica*), Proso millet (*Panicum miliaceum* L.) and Kodo millet (*Paspalum scrobiculactum* L.) grown on restricted places and mainly expressed as nutri-cereals. The millet crops little millet (*Panicum Sumatrense* Roth ex. Roem. and Schult). Barnyard millet (*Echinochloa Frumentacea* Link) are also considered as a part of nutri-cereals even though the area under cultivation is merger and very less. The two other crops also accounted in millets in India viz. grain Amaranthus (*Amaranthus hypochondriacus*) and buck-wheat (*Fagopyrum esculentum*). The area and production of different millets reported in different sources were showed in table 1, indicates the major share of pearl millet and sorghum to total millet production. Area under nutri-cereals (excluding maize) is 12.7 million ha with production of 17.3 million tonnes [15,16]. The nutri-cereal production (excluding maize) is 5.48% of the total food grain production and 6.01% of total cereal production, respectively. The major sorghum growing states are Maharashtra, Karnataka, Madhya Pradesh, TamilNadu, Rajasthan and Andhra Pradesh; while pearl millet is grown mainly in Rajasthan, Uttar Pradesh, Haryana, Maharashtra and Gujarat. The finger millet is grown in Karnataka and Tamil Nadu with their respective contribution of 64.8% and 16.2% to the total finger millet production; while the Karnataka, Rajasthan and Maharashtra are the three major state growing nutri-cereals with total contribution to 82.26% to total nutri-cereals production in India in 2022-23. The ecological suitability of millets were reported by [17-20]; while [21-23] indicating their suitability in tropical and subtropical climatic conditions, drought prone area and hilly terrain. The states such as Karnataka, Maharashtra, Rajasthan and Gujarat are growing millets under irrigation condition with significantly higher input investment [24-26]. The nutritional importance of millets (Table 2) indicates potential of millets to provide minerals nutrients including micronutrients. The biofortified varieties of millets (Table 3) indicate their potential to counteract the problems of hidden hunger born out of micronutrient deficiency. The nutrient importance of millets is also expressed by their medicinal proper-

ties. The consumption of finger millet to reduce risk of diabetes, high blood pressure and gastro-intestinal tract disorder was cited in [27]; while use of pearl millets for treatment of constipation, as an alternative food for weight control and to reduce the risk of chronic diseases such as diabetes was reported in [28,29]. The bio-active compounds in millets were ferulic acid, phytic acid, phytates, phenols and tannins, dietary fiber, thiamine, riboflavin, niacin, folic acid, Vitamin A and Vitamin C. The list of processed products from different millets is given in table 4 indicating the suitability of millets for processing and value addition. The information on production practices for different millets is given in table 5.

Millets	Particular	Years						
		2011-12	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Sorghum	Area (million ha)	6.2	5.6	5.0	4.1	4.8	4.4	3.80
	Production (million tonnes)	6.0	4.6	4.8	3.5	4.8	4.8	4.2
	Productivity (kg/ha)	957	812	960	849	989	1099	1110
Pearl millet	Area (million ha)	8.8	7.5	7.5	7.1	7.5	7.7	6.7
	Production (million tonnes)	10.3	9.7	9.2	8.7	10.4	10.9	9.6
	Productivity (kg/ha)	1171	1305	1231	1219	1374	1420	1436
Ragi, barley and other small millets	Area (million ha)	2.6	2.3	2.4	1.9	2.1	2.1	2.2
	Production (million tonnes)	3.9	3.6	4.2	3.2	3.7	4.0	3.5
	Productivity (kg/ha)	-	-	-	-	-	-	-
Total Nutri-Cereals (excluding maize)	Area (million ha)	17.6	15.4	14.9	13.1	14.4	14.2	12.7
	Production (million tonnes)	20.2	17.9	18.2	15.4	18.9	19.7	17.3
	Productivity (kg/ha)*	1590	1750	1934	1944	1991	2128	2247

Table 1: Changes in area, production and productivity of millets for last ten years [15,16].

(*: Including maize, sorghum, pearl millet, finger millet, barley and small millets).

S. No.	Name of crop	Inorganic nutrient content (mineral nutrient content)	References
1.	Sorghum (*Sorghum bicolor*)	Calcium (11-586 mg 100 g^{-1}), Iron (0.9-20.0 mg 100g^{-1}), 4.40-21.10 % Protein, 2.10-7.60 % fat.	[33]
2.	Pearl millet (*Pennisetum Glaucum*)	Calcium (25 - 42 mg 100 g^{-1}), Iron (3.0 - 11.0 mg 100 g^{-1}), zinc (2.2 - 3.1 mg 100 g^{-1}), 4.8 - 5 % fat, 8.0 - 11.8 % protein.	[29]
3.	Barley (*Hordium vulgare*)	9.46-11.33 % protein, 2.02-2.38 % mineral, 3.90 - 6.59 % crude fiber	[34,35]
4.	Finger millet (*Elusine Coracana*)	Calcium (398 mg 100g^{-1}), Magnesium (78-201 mg 100g^{-1}), Phosphorus (130-250 mg 100g^{-1}), Iron (3.3-14.89 mg 100g^{-1}), zinc (2.3 mg 100g^{-1}), 7.7 % protein, 1.8 % fat.	[11]
5.	Foxtail millet (*Setaria italicaa*)	11.5-12.3 % protein, 2.38-3.4 % fat, 31 Calcium (31), Zinc (2.4 mg 100g^{-1}) and Iron (2.8 mg 100g^{-1})	
6.	Proso millet (*Panicum miliacium*)	12.5 % protein, 1.1 % fat/lipids.	[10]
7.	Little millet (*Panicum sumatrans*)	10.13 % protein, 3.89 % fat/lipids.	
8.	Barnyard millet (*Echinoclua crusgalli*)	6.2 % protein, 2.2 % fat, 20-22 calcium (42 mg 100g^{-1}), Zinc (3.1 mg 100g^{-1}) and Iron (8.0 mg 100g^{-1}).	[11]
9.	Kodo millet (*Paspalum scrobiculactum*)	9.8 % protein, 1.3 % fat, Calcium (27 mg 100g^{-1}), Zinc (0.7 mg 100g^{-1}) and Iron (0.5-5.0 mg 100g^{-1}).	

Table 2: Nutritional characteristics of major and minor millets.

Crop	Varieties	Reference
Pearl millet	Dhanashakti (81 mg kg^{-1} Fe and 43 mg kg^{-1} Zn); HHB-299 (73 mg kg^{-1} Fe and 41 mg kg^{-1} Zn) AHB-1200 (77 mg kg^{-1} Fe and 39 mg kg^{-1} Zn), AHB-1269 (91 mg kg^{-1} Fe and 43 mg kg^{-1} Zn), RHB-234 (84 mg kg^{-1} Fe and 41 mg kg^{-1} Zn), RHB-233 (83 mg kg^{-1} Fe and 46 mg kg^{-1} Zn), HHB-311 (83 mg kg^{-1} Fe and 39 mg kg^{-1} Zn)	[19]
Sorghum	Increase in zinc and iron concentration by 1.77 - 3.76 mg kg^{-1} and 9.06 mg kg^{-1}, respectively due to application of ZnSO4 @ 50 kg ha^{-1} (soil application), FeSO4 @ 50 kg ha^{-1} (soil application), foliar spray of Zn @ 0.5 % and foliar spray of Fe @ 1.0 % at 45 days after sowing.	[36]
Finger millet	Analysis of 319 genotypes of finger millets showed that concentration of zinc in grain varies from 10 – 86 µg g^{-1}. The genotypes such as GEC331 and GEC164 showed greater uptake and translocation; while genotypes GEC-164 and GEC-543 showed higher grain zinc concentration.	[37]

Table 3: Nutrient enriched varieties of different millets and report of micronutrient enrichment through fertilization.

Name of millet	Product prepared	References
Sorghum	Puffs, Extruded snacks (mixture of sorghum, rice, finger millets, corn and wheat), Extruded flakes (mixture of sorghum, wheat and corn flour), Idli, Upma, dosa, Pongal mix, pizza base (mixture of sorghum, pearl millet and finger millet or foxtail millet flour), sorghum bran peda, sorghum based energy bar, sorghum bran fryums, Biscuit, Bushera, Dambu, Ogi (Porridge),	[38,39]
Pearl millet	Puffs, Rawa/Suji, roti, Vermicelli, pasta, cookies, bread and bun, cake, Fura, Dambu	
Finger millet	Laddu (mixture of finger millet and pearl millet), Rawa/Suji, roti, Vermicelli, Pasta, Cookies, bread and bun, cake, Burukutu and Pito (beverages), togwa. Masvusvu, Dambu	
Foxtail millets	Puffs, Rawa/Suji, roti, Vermicelli, Pasta, Cookies, bread and bun, cake	

Table 4: Products prepared from different millets.

The input responsiveness of millets can be defined by increase in grain and straw yield and nutrient uptake. The significantly higher yield with irrigation/fertilization was reported in [25] and [30] for pearl millets and sorghum, respectively. The increasing the concentration of zinc in grain with zinc fertilization was reported by [31]; while growth improvement and nutritional concentration increase with zinc fertilization in finger millet was reported in [32]. This responsiveness of millets will be a good indicator for their extending production over large area with more resource use efficiency than input intensive cereal production system. The major research themes for millets at present are identifying the mineral enrichment capacity of millet grain for development of nutrient dense millets varieties, identifying new area for millet cultivation across the county, quantifying input responsiveness of millets, study of effect of cultivation methods and crop establishment method of millets. The policy related activities include processing and value addition suitability of millets, preparation of different ready to eat products from millets, establishment and promotion of millet processing industries and also promotion of millets products at different food establishment.

Potential of millets for Meghalaya (new non-conventional region)

- Intercropping of millets with rice, maize and soybean in different land configuration.
- Use of upland and degraded slope area for millet cultivation where rice productivity is low due to water and nutrient stress.
- Use as intercrop in orchard.
- Possibility as a source of fodder.
- Utilization of residual soil moisture as after early season rice or rainfed rice.
- Commercial organic seed production and organic millet production (to harness the benifits of organic cultivation in NEH region).
- Incorporation in diet and potential interventions for value addition and processing.

Name of crop	Varieties	Duration (days)	Sowing time	Sowing method	Seed rate	Spacing	Seed treatment	Nutrient requirement (kg $N:P_2O_5:K_2O$ /ha)	Weed management	Water management	Insect pest	Disease	Yield
Sorghum [40]	CSH-1, CSH-9, CSH-14, Phule Yashoda, PKV Kranti.	115-135	*Kharif*: Within two weeks from onset of Monsoon OR first fortnight of July; *Rabi*: 3rd week of September to 1st week October.	Drilling (Broadcasting for fodder)	8-10 kg/ha	45 cm × 12 cm. 45 cm × 15 cm	Thiram or Vitavax @ 2.5g kg^{-1} seeds. *Azotobactor or Azospirillum* @ 25g per 1 kg seeds.	Rainfed: 25-60:20-30:00 Irrigated: 80-100:40-50:40-50	Grow cover crops; mulching; crop rotation with catch crops, and intercropping; two hand weeding 20-25 days and 40-45 days after sowing; Atrazine 0.75-1.0 kg a.i./ha as preemergence, .Metolachlor 1.0-1.5 kg a.i./ha. as rep-emergence	Water sipping crop and use water efficiently; 425-610 mm water requirement; four irrigation at grand growth stage, flag-leaf stage, flowering stage and grain-filling stage. Soil moisture conservation practices such as deep ploughing, compartmental bunding, ridges and furrow, etc.	Shoot fly, stem borer, sorghum midge, shoot bug, head bug, Aphid, Mite.	Downey mildew, rust anthracnose, grain mold, loose smut.	Irrigated: 5 t ha^{-1} and Rainfed: 2.5-3.0 t ha^{-1}
Pearl millet [41] " 7	HB-1, HB-2, HB-3, Pusa-266, Pusa composite-334, Pusa Composite-443, Pusa Composite-383	75-80	Onset of Monsoon, first fortnight of July. Transplanting: August (in main field);	Drilling and transplanting	4 - 5 kg/ha for drilling and 2 kg/ha for transplanting.	45 × 10-15 cm or 50 × 10 cm	Seed treatment with 20 % salt solution to remove ergot infescted seeds; Seed treatment with mixture of 2g emisan and 4g thiram per kg seed for downey mildew management. *Azotobactor or Azospirillum* @ 25g per 1 kg seeds.	10-15 t FYM or Compost ha^{-1}; 100-120: 40-60:30-40; 3 % urea spray in rainfed agriculture.	3-5 week is critical for weed; timely weeding and avoid deep ploughing near plants; emergence application of Atrazine @ 0.5 kg a.i./ha	Two irrigation at critical growth stages; earhead emergence stage, crop do not tolerate water logging.	White grub, shoot fly, hairy caterpillar, Termite	Downey mildew, Ergot, Rust, Smut, Blast	Irrigated: 3.0-3.5 t ha^{-1} Rainfed: 1.2-1.5 t ha^{-1}

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Finger millet (*Eleusine Coracana* (L.) Gaertn.) (Wider adaptability and rich source of calcium, phosphorus and minerals) [42]	GPU-28, OUAT-2 (Shubra), Chilika, VL315, MR-6 (Divya) and GPU-48	120-135 days	June - July (Summer irrigated: January - February)	Drilling and transplanting	6 - 8 kg/ha for drilling and 4 - 5 kg/ha for transplanting	22.5 - 30.0 cm × 7.5 - 10 cm (2 seedling per hill for transplanting)	*Azospirillum* + *Aspergillus awamori* @ 25g/kg seeds	40:20:20 to 60:30:30 for rainfed and 90:45:45 to 100:50:50 for irrigated field.	First 45 days are critical; 2 - 3 weeding; Pre-emergence herbicide: Isoproturon @ 0.75 kg a.i./ha Post-emergence: 2, 4-D @ 1 kg a.i./ha.	tillering and flowering stage is considered as critical stages for irrigation; removal of excess water from field; ridges and furrow for irrigation	Pink stem borer (*Sesamia inferens*) and cut worm (*Spodoptera exigua*).	Blast (*Pyricularia grisea*), leaf blight (*Helminthosporium nodulosum*), wilt or foot rot (*Sclertium rolfsi*), leaf spot , streak virus	
Foxtail millet (*Setaria italica*) (Short duration, Tolerant to low soil fertility and drought) [42]	PS-1, Sri Lakshmi,, SR 51, PRK 1, Co 7, TNAU-43.	80-100 days	June - July (Summer: January - February)	Drilling and broadcasting	Drilling: 8 - 10 kg/ha; Broadcasting: 15 kg/ha	25-30 cm × 8-10 cm	-	20-40: 20-30: 00	First 45 days are critical; Two manual weeding at 15-20 days after sowing (DAS) and 30-35 DAS; Pre-emergence herbicide: Isoproturon @ 0.50- 0.75 kg a.i./ha + one hand weeding at 30-45 day after sowing.	Grown as rainfed crop; 1-2 irrigation to boost crop yield. Drain out excess water.	Shoot fly (*Atherigona pulla*)	Blast (*Pyricularia setariae*), Rust (*Uromyces setariae-italica*), and Downey mildew (*Sclerospora graminicola*)	
Proso millet (*Panicum miliaceum* L.) (Short duration, tolerate to heat and drought) [42]	GPUP 8, GPUP 21, Pratap Cheena 1, TNAU 145, PRC 1, TNAU 164, TNAU 151	60-90 days	March (Irrigated catch crop), May - June, September - October (Late *kharif* crop)	Drilling and broadcasting	Drilling: 10 kg/ha; Broadcasting: 15 kg/ha	25 cm × 10 cm	-	20-40: 20: 00	First 45 days are critical; Two manual weeding at 15-20 days after sowing (DAS) and 30-35 DAS.	Irrigation at tillering stage; For summer season crop: 2-4 irrigations with first irrigation at 25-30 day and second at 40-45 days.	Shoot fly (*Atherigona pulla*)	Smut (*Sphecelotheca destuens*)	

Kodo millet (*Paspalum scrobiculactum* L.) (Long duration, grow well in shallow and deep soil) [42]	Vamban 1 (PMV 20), PBK 155 and Jawahar kodo 48, KK 2, Jawahar kodo-13	85-105 days	June - July	Drilling and broadcasting	Drilling: 10 kg/ha; Broadcasting: 15 kg/ha	22.5 cm × 10 cm	Carboxin @ 2g/kg seeds OR carboxin 1g + *Trichoderma viride* 2.5g/kg for head smut management.	20-40: 20: 00	First 45 days are critical; Two manual weeding at 15-20 days after sowing (DAS) and 30-35 DAS; Pre-emergence herbicide: Isoproturon @ 0.50- 0.75 kg a.i./ha + one hand weeding at 30-45 day after sowing.	Grown as rainfed crop; 1-2 irrigations if needed. Drain out excess water	Shoot fly (*Atherigona pulla*)	Head smut	
Little millet (*Panicum Sumatrense* Roth ex. Roem. & Schult). (Short duration, withstand to drought and water logging) [42]	CO 6 (TNAU 63), Paiyur 2, OLM 203, OLM-36, OLM-20, Co-5 (Samai).		June - July	Drilling and broadcasting	Drilling: 8 kg/ha; Broadcasting: 12 kg/ha	22.5 cm × 8 - 10	Caebendazim or carboxin 2g / kg seeds.	20-40: 10-20: 20	First 45 days are critical; Two manual weeding at 15-20 days after sowing (DAS) and 30-35 DAS.	-	Shoot fly (*Atherigona pulla*)	Rust (*Uromycis linearis*)	
Barnyard millet (*Echinochloa Frumentacea*) (Fastest growing, voluminous fodder) [42]	VL Madira 172, VL Madira 181, Pratap Sanwa 1, PRJ 1.	75-115 days	February - March, September - October	Drilling and broadcasting	Drilling: 8 kg/ha; Broadcasting: 10 - 12 kg/ha	22.5 cm × 10 cm	Carbendazim 2g / kg seeds for grain smut management	20-40: 20: 20	First 45 days are critical; Two manual weeding at 15-20 days after sowing (DAS) and 30-35 DAS; Pre-emergence herbicide: Isoproturon @ 0.50- 0.75 kg a.i./ha + one hand weeding at 30-45 day after sowing.	Grown as rainfed crop; irrigation at panicle initiation stage is needed. Drain out excess water	Shoot fly (*Atherigona pulla*)	Grain smut	

Table 5: Recommended production practice of millets in India.

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Constraints and limitation

- Lack of state or region specific recommendation for high production on commercial scale in different state of NEH region.
- Lack of awareness about prospects of organic millet production.
- Lack of varietal development and least priority to millet production in all fronts.
- Constraints in market interventions and value addition due to less produce availability.
- High diversity of agro-climatic condition making wider application of recommendation a difficult task.

Intervention for millets production

- Seed and input distribution required for millet production.
- Conducting awareness campaign and organizing training on millet production practices.
- Establishing linkage between millet growing region and millet cultivation in NEH region.
- Development of human resource for millet cultivation and value addition.
- Promotion of millets-based products in semi-urban and urban area (including snacks prepared from millets).

Bibliography

1. Anonymous. "India State of Forest Report". Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India" (2019a).

2. Prokop P. "The Meghalaya plateau: Landscapes in the abode of the clouds In: Landscape and landforms of India (Kale V.S. Edn) (2014). World Geomorphological Landscapes, Springer Science Business Media Dordrecht (2014).

3. Guhathakurta P., *et al.* "Observed Rainfall Variability and Changes over Meghalaya State". Met Monograph No.: ESSO/IMD/HS/Rainfall Variability (2020).

4. Shahane AA and Behera UK. "Significance of promotion and awareness creation of organic certification procedure by agricultural colleges in meghalaya state". *Acta Scientific Agriculture* 6.10 (2022): 56-60.

5. Anonymous. "Handbook on area, production and yield of principal crops in Meghalaya, (2019) (Including land use statistics and irrigation statistics) from 2013-14 to 2017-18". Volume -V. Directorate of Economics and Statistics, Government of Meghalaya, Meghalaya, India.

6. Layek J., *et al.* "Cereal+ legume intercropping: An option for improving productivity and sustaining soil health". *Legumes for Soil Health and Sustainable Management* (2018): 347-386.

7. Ramkrushna GI., *et al.* "Assessing maize based cropping systems for higher productivity and income under shifting cultivation in eastern Indian Himalayas". *Indian Journal of Soil Conservation* 50.2 (2022): 101-106.

8. Ansari MA., *et al.* "Maize production technology highlighted in North East India". Training Manual RCM (TM)-05. ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal 795004 (2015): 44.

9. Babu S., *et al.* "Impact of land configuration and organic nutrient management on productivity, quality and soil properties under baby corn in Eastern Himalayas". *Scientific Reports* 10.1 (2020): 16129.

10. Hariprasanna K. "Biofortified millets to support national nutrition mission. 93-101" In: Finger millet: Nature's master grain-A souvenir (Nagaraja T.E., Deepak C.A., Sukanya T.S., Shadakshari Y.G., Tonapi VA. and Prasad S.R. Eds.) (2022), international conference on harnessing the potential of finger millet for achieving food and nutritional security: Challenges and Prospects (2022).

11. Ramashia SE., *et al.* "Processing, nutritional composition and health benefits of finger millet in sub-saharan Africa". *Food Science and Nutrition* 39.2 (2019): 253-266.

12. NAAS. "Role of Millets in Nutritional Security of India". Policy Paper No. 66, National Academy of Agricultural Sciences, New Delhi, India (2013): 16.

13. NAAS. "Promoting millet production, value addition and consumption". Policy Paper No. 114, National Academy of Agricultural Sciences, New Delhi, India (2022): 24.

14. Shahane AA and Behera UK. "Theoretical basis for introduction of crops in non-conventional zone in organic production system for climate resilient agriculture" (2022a). In: 4th International Conference on "Global Efforts on Agriculture, Forestry, Environment and Food Security (GAFEF-2022)" at Institute of Forestry, Tribhuvan University, Pokhara Campus Pokhara, Nepal on September 17-19 (2022): 52.

15. Anonymous. Annual Report 2021-22, "Department of Agriculture, cooperation and farmer welfare, Ministry of Agriculture, cooperation and farmer welfare, Govt. of India (2022).

16. Anonymous. Annual Report 2022-23, "Department of Agriculture, cooperation and farmer welfare, Ministry of Agriculture, cooperation and farmer welfare, Govt. of India (2023).

17. Abdullah K., *et al.* "Testing the climate resilience of sorghum and millet with time series data". *Cogent Food and Agriculture* 8.1 (2022): 2088459.

18. Chaturvedi P., *et al.* "Sorghum and pearl millet as climate resilient crops for food and nutrition security". *Frontiers in Plant Science* 13 (2022): 503.

19. Satyavathi CT., *et al*. "Pearl millet: a climate-resilient nutricereal for mitigating hidden hunger and provide nutritional security". *Frontiers in Plant Science* (2021): 1828.

20. Wilson ML and VanBuren R. "Leveraging millets for developing climate resilient agriculture". *Current Opinion in Biotechnology* 75 (2022): 102683.

21. Das P., *et al.* "Automated mapping for long-term analysis of shifting cultivation in Northeast India". *Remote Sensing* 13.6 (2021): 1066.

22. Nagaraj N., *et al.* "Sorghum and pearl millet economy of India: Future outlook and options". *Economic and Political Weekly* (2013): 74-81.

23. Sanjana Reddy P., *et al.* "Performance and stability of pearl millet varieties for grain yield and micronutrients in arid and semi-arid regions of India". *Frontiers in Plant Science* 12 (2021): 670201.

24. Gowda MC., *et al.* "Estimation of energy requirement for finger millet (*Eleusina G*.) cultivation in Karnataka (India)". *International Journal of Applied* 5.1 (2010): 1-8.

25. Yadav M., *et al.* "Effect of different nutrient management practices on growth, yield attributes and yield of transplanted pearl millet (*Pennisetum glaucum* L.)". *International Journal of Plant and Soil Science* 33.22 (2021): 260-266.

26. Kurai T., *et al.* "Efficient rates of nitrogenous fertilizer for irrigated sweet sorghum cultivation during the post-rainy season in the semi-arid tropics". *European Journal of Agronomy* 71 (2015): 63-72.

27. Ramashia SE., *et al.* "Processing, nutritional composition and health benefits of finger millet in Sub-Saharan Africa". *Food Science and Nutrition* 39.2 (2019): 253-266.

28. Dias-Martins AM., *et al.* "Potential use of pearl millet (*Pennisetum glaucum* (L.) R. Br.) in Brazil: Food security, processing, health benefits and nutritional products". *Food research international* 109 (2018): 175-186.

29. Nambiar VS., *et al.* "Potential functional implications of pearl millet (*Pennisetum glaucum*) in health and disease". *Journal of Applied Pharmaceutical Science* 1.10 (2011): 62-67.

30. Oberoi HK., *et al.* "Response of hybrid fodder sorghum in relation to sulfur fertilization and irrigation regimes in semi-arid region of North West India". *Journal of Plant Nutrition* (2022): 1-21.

31. Singh R., *et al.* "Effect of nitrogen and zinc fertilizer on Zn biofortification in pearl millet (*Pennisetum glaucum*)". *Indian Journal of Agronomy* 59.3 (2014): 474-476.

32. Pradhan A., *et al.* "Effect of zinc fertilization on growth and yield of finger millet (*Eleusine coracana* L. Gaertn.)". *International Journal of Environmental Science and Technology* 5.3 (2016): 1477-1487.

33. Abah CR., *et al.* "Sorghum grains: nutritional composition, functional properties and its food applications". *European Journal of Nutrition and Food Safety* 12.5 (2020): 101-111.

34. Jood S and Kalra S. "Chemical composition and nutritional characteristics of some hull less and hulled barley cultivars grown in India". *Food Nahrung* 45.1 (2001): 35-39.

35. Lee J., *et al.* "Variability in nutrient composition of cereal grains from different origins". *SpringerPlus* 5.1 (2016): 1-6.

36. Mishra JS., *et al*. "Biofortification of post-rainy season sorghum (*Sorghum bicolor*) with zinc and iron through fertilization strategy". *Indian Journal of Agriculture Sciences* 85.5 (2015): 721-724.

37. Yamunarani R., *et al.* "Genetic diversity of grain zinc concentration in finger millet genotypes: Potential for improving human zinc nutrition". *The Crop Journal* (2016).

38. Dayakar Rao B., *et al*. "Technologies of Millet Value Added Products". Centre of Excellence on Sorghum, ICAR-Indian institute of Millets Research. Rajendranagar, Hyderabad, India. (2016) pp 48.

39. Amadou I., *et al*. "Millet based traditional processed foods and beverages-A review". *Cereal Foods World* 56.3 (2011): 115-121.

40. Mishra JS., *et al*. "Sorghum". In: Text book of field crop production Volume-I, ICAR publication, New Delhi, India (2012): 137-181.

41. Rana KS and Bana RS. "Pearl millet". In: Text book of field crop production Volume-I, ICAR publication, New Delhi, India (2012): 182-201.

42. Gupta A and Gupta HS. "Minor millets". In: Text book of field crop production Volume-I, ICAR publication, New Delhi, India (2012): 227-247.