Conservation and Utilization Status of Small Millets in Nepal

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Abstract

Millets are small seeded cereals grown for human consumption and animal feed in various African and Asian countries. They have an excellent nutritional properties and are less vulnerable to biotic and abiotic stresses compare to other major staples including rice, wheat, and maize. Major small millets grown in Nepal include finger millet, proso millet, and foxtail millet. There are thousands of germplasm accessions of these millets in Nepal either in ex situ or at on-farm conditions yet to be explored and utilized. These millets are neglected from policy makers, researchers, development workers, and even by farming communities. Conservation and utilization of these millets for their genetic improvement could increase food and nutrition security of the country. In this chapter, we introduce the nutritional significance and climate-resilient properties of these millets, highlight their production, conservation and utilization status in Nepal, and discuss challenges and opportunities for their genetic improvement in Nepalese context.

Keywords

Finger millet · Foxtail millet · Proso millet · Small millets · Nepal

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2.1 Small Millets and Their Significance in Nepal

Millets are the group of crops belongs to grass family characterized by small seeds. They are well known for their wide adaptability to diverse but adverse agro-ecological environments in the world, particularly Africa and Asia. Among the millets, crops with smaller plants and smaller seeds such as barn yard millet, finger millet, foxtail millet, kodo millet, little millet, proso millet, etc. belong to the group of small millets. Small millets can be grown in marginal environments with minimum level of inputs. Their grain has an excellent nutraceutical value since they are rich in minerals, calories, and proteins (Devi et al. 2014). All of these crops are less vulnerable to various biotic and abiotic adversities compared to other major food crops such as rice, wheat, and maize. Developing new varieties in small millets with modern approaches is in less priority so far for any national and international research programs because of bigger attention to major staple cereals such as rice, wheat, maize, etc. This is more evident in developing countries like Nepal. In the context of climate change, small millets are the crops of the future with great potentiality to cope with food and nutrition insecurity for the global population (Goron and Raizada 2015). Small millets have multiple significance in Nepalese context.

2.1.1 Small Millets for Food Security

Finger millet is the fourth most important food crops in Nepal in terms of area and production after rice, maize, and wheat. Finger millet is consumed mainly as *Dhindo* (porridge), *Roti* (pancake), and *Khole* (millet soup) (Gaihre et al. 2021) across the hills and high mountains. Proso millet and foxtail millet are consumed as *Khir* (pudding), *Bhaat* (boiled like rice) (Ghimire et al. 2017). In the most food deficit regions of the country such as mountain districts of Karnali and Far-western provinces, proso millet and foxtail millet have significant contribution in food security together with finger millet because growing rice and wheat is not possible in those areas due to adverse climatic conditions whereas transportation of food grains from outside is very expensive due to poor access to roads.

2.1.2 Small Millets for Health and Nutrition

All crops belonging to small millets are nutrient dense as compared to major staples since they are gluten-free and rich in minerals, micronutrients, vitamins, proteins, rare amino acids, and fibers (Table 2.1). They are the most important food crops of economically suppressed but physically hard working people. Due to increasing trend of non-communicable diseases like diabetes, hypertension, cholesterol etc., inclusion of small millets in the regular meal is also increasing in urban populations since they are getting more conscious to their health and aware on the health benefits of small millets.

Table 2.1 Comparative nutrient profile of small millets and major staples grown in Nepal (DFTQC 2017)

Commodity	Protein (g)	Fat (g)	Carbohydrate (g)	Minerals (g)	Fiber (g)	Energy (kcal)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Foxtail millet	12.3	4.3	60.9	3.3	8	331	31	290	12.9	0.59	0.11	3.2
Finger millet	7.3	1.3	72	2.7	3.6	328	344	283	3.9	0.42	0.19	1.1
Proso millet	11	4.22	72.9	3.25	1	378	8	28.5	3.0	–	–	–
Rice	6.8	0.5	78.2	0.6	0.2	345	10	160	0.7	0.21	0.06	1.9
Maize	11.1	3.6	66.2	1.5	2.7	342	10	348	3.3	0.42	0.1	1.8
Wheat	12.1	1.7	69.4	2.7	1.9	341	48	355	4.9	0.49	0.17	4.3

2.1.3 Small Millets for Animal Feed

Finger millet grains and fermented by-products are used as good feedstuff to animals while its green as well as dried straw is utilized as highly nutritious forage for livestock with up to 60% digestible nutrients (Gupta et al. 2017). In Nepal, small millets are used in regular feed (*Kundo*) of draft, milk, and meat animals as well as poultry feed (*Daanaa*). Green and dry straw of these crops are used by Nepalese farmers as an integral part of their animal fodder.

2.1.4 Small Millets for Climate Resilience

Small millets are grown in marginal lands with no fertilizer, pesticides, and irrigation since they are less vulnerable to various biotic and abiotic adversities arisen due to climate change compare to other major food crops such as rice, wheat, and maize. Since they are hardy crops, they can tolerate unpredictable environmental change in dry mountain areas of Nepal. Most of the small millets are short duration crops, thus can be used as catch crops or crop insurance when there is low rainfall and rice transplanting is not possible, or even when rice crop is washed out by heavy flooding.

2.1.5 Small Millets for Organic Agriculture and Agro-Tourism

Small millets are grown in remote mountain areas thus by default organic since farmers don't use any chemical fertilizers and pesticides for these crops. Millets flour is used for the preparation of modern bakery products such as pancakes, cakes, biscuits, namkins, noodles, pasta, momos, sweets, etc. are also gaining popularity in recent years. The finger millet grain is used for making high-quality traditional liquors after fermentation. These crops have been an integral component of agro-tourism in Nepal due to its *dhindo* and high quality home-made wine *raksi* in the menus of hotels and restaurants.

2.2 Production Status

Globally, foxtail millet and finger millet ranked third and fourth among millet crops after sorghum and pearl millet (Upadhyaya et al. 2007). Precise data of area and production under each small millets are not available in many countries because the production statistics of these crops had often been clubbed with other millets (Upadhyaya et al. 2010). Finger millet is the fourth most important crop of Nepal after rice, maize and wheat in terms of area and production. A total of 326,443 t of finger millet is produced in 2021 from 265,401 ha area with average productivity of 1.23 t/ha (MoALD 2022). Area of finger millet has been static over last three decades but the production and productivity is slightly increased (Fig. 2.1). Proso millet is the

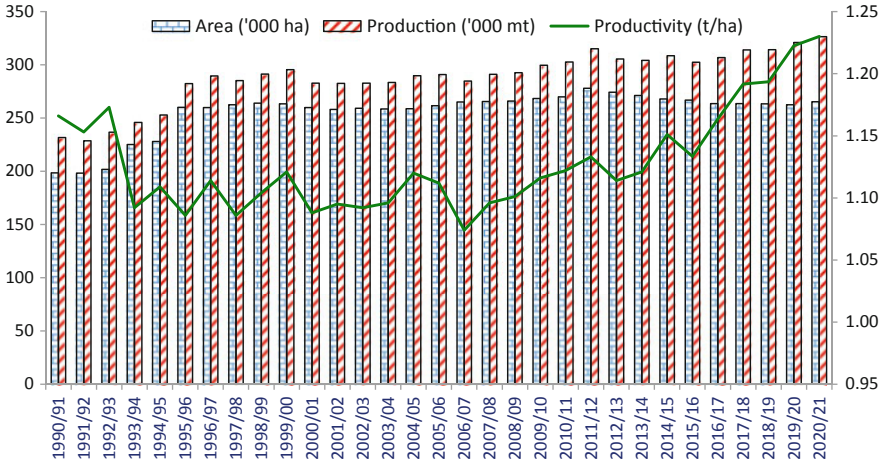

Fig. 2.1 Area, production, and productivity trend of finger millet in Nepal for the last three decades. (Source: MoALD 2022)

second important crop among millets, grown in around 2000 ha with the productivity of 0.81 t/ha whereas foxtail millet is grown in around 1500 ha with the productivity of 1.04 t/ha (DoA 2015). Production data of barn yard millet and little millet in Nepal is not available so far since they are growing in negligible area.

2.3 Conservation Status

2.3.1 Analysis of Conservation Threats

The four-cell analysis is a basic technique of understanding amount and distribution of traditional crop diversity at community level (Sthapit et al. 2006). This tool roughly estimates the risk of genetic diversity loss and the reasons why a species is in the risk zone (Joshi et al. 2020a; Dulloo et al. 2021). Based on the available national statistics and our own experience, we divided our five small millets into four cells (Fig. 2.2) to assess their abundance or conservation threats at national level. In our assessment, finger millet has very minimum threats since it is grown by many households in larger areas; however, many finger millet landraces are under threats since their cultivation is in declining trend. Proso millet is cultivated in larger areas but by less number of households or in particular niches. In contrast, foxtail millet is cultivated by more households than proso millet but in smaller areas across the country. Both proso millet and foxtail millet have moderate threat for their conservation and we need to prioritize these crops for on-farm conservation through community seed banks as well as ex situ conservation at the national and international Genebanks. The serious conservation threats are faced by little millet and barn yard millet since both of these crops are grown by very few number of households in

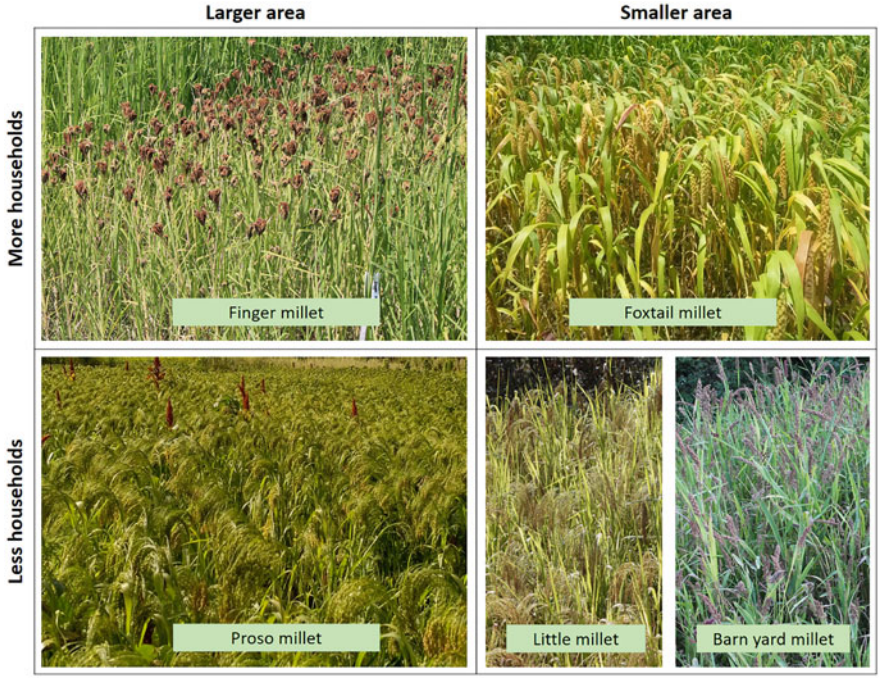

Fig. 2.2 Four-cell analysis of small millets grown in Nepal

very small parcels of their field. Our major focus for these two crops should be on exploration and collection, awareness raising and ex situ conservation. Replacement of landraces by new improved varieties is not so evident on small millets in Nepal but the threat is there since farmers are reluctant to grow either these crops or portfolio of landraces of these crops.

2.3.2 Inter and Intra-specific Diversity

Nepal has very wide ranges of altitudinal variation and millets can be grown from the lowest of 60 m up to 3500 m altitude. Similarly, the variation in land type, topography, rainfall, temperature, day length, etc. is also evident within the small boundary of the country. Due to these variations, there is high genetic diversity in small millets, especially in finger millet and foxtail millet. Among the millets, finger millet is the first important crop in Nepal in terms of area and production followed by proso millet and foxtail millet. Barn yard millet, little millet, and kodo millet are the other small millets that have been reported to be grown in parts and parcels of the country (Table 2.2). Not only species diversity, there is plenty of intra-specific diversity within finger millet and foxtail millet. Lower diversity of landrace is observed barn yard millet, little millet, and proso millet. Landraces are named based on grain color,

Table 2.2 List of small millets with their distribution and related species found in Nepal

S. No.	Common name	Nepali name	Scientific name	Distribution	Related species found in Nepal (Press et al. 2000)
1.	Finger millet	Kodo	*Eleusine coracana* (L.) Gaertn.	Widely distributed across the country including wild species *E. indica* (L.) Gaertn.	*E. indica* (L.) Gaertn.
2.	Foxtail millet	Kaaguno	*Setaria italica* (L.) P. Beauv.	Scattered in high hills of Karnali, Gandaki and Bagmati provinces	*Forbesiana*, *geniculata*, *glauca*, *pallidefusca*, *palmifolia*, *plicata*, *tomentosa*, *verticillata*, *viridis*
3.	Proso millet	Chino	*Panicum miliaceum* L.	Localized mainly in high hills of Karnali and Sudur pashchim province	*Antidotale*, *humidorum*, *notatum*, *paludosum*, *psilopodium*, *repens*, *sumatrense*, *trypheron*, *walense*
4.	Little millet	Dhaan kodo	*Panicum sumatrense* Roth. & Schult	Rarely found in small areas of Mid hills	
5.	Barn yard millet	Saamaa	*Echinochloa frumentacea* Link.	Rarely found in small areas of Mid hills	*Colona*, *crus-galli*, *crus-pavonis*, *glabrescens*, *picta*, *pyramidalis*, *stagnina*
6.	Kodo millet	Kodee	*Paspalum scrobiculatum* L.	Rarely found in small areas of Mid hills, mainly wild	*P. conjugatum* and *P. distichum*

shape and size of the heads/panicles, planting season, maturity duration, eating quality, etc. (Table 2.3).

2.3.3 Ex Situ Collection and Gaps

After the establishment of National Agriculture Genetic Resources Centre (Genebank) in 2010, collection and conservation of millets genetic resources got high priority. Among small millets, Nepal Genebank have the largest holdings of

Table 2.3 Conservation status of different millet species in Nepal Genebank and common landraces

Crop	Number of accessions	Name of common landraces
Finger millet	1175	Dalle, Jhapre, Chulthe, Laribari, Paundure, Thulo, Sano, Lurke, Lafre, Nangre, Nangkatuwa, Matyangre, Lampate, Asoje, Kattike, Mudke, Mangsire, Temase, Chaumase, Lekali, Pahenlo, Rato, Kalo, Seto, Dudhe, Jwain, Samdhi, Bhanchuwa, Chyalthe, Jhope, Tauke etc.
Foxtail millet	55	Kalo kaguno, Seto kaguno, Pahenlo kaguno, Rato kaguno, Maal kaguno, Bariyo, Aulel, Ande kaguno, Tinmase kaguno etc.
Proso millet	51	Kalo chino, Seto chino, Dudhe chino, Rato chino, Hade chino, Kaptede, Katibade, Kolte chino, Batale chino, etc.
Barn yard millet	6	Seto sama, Rato sama
Little millet	3	Dhan kodo, Suji kodo

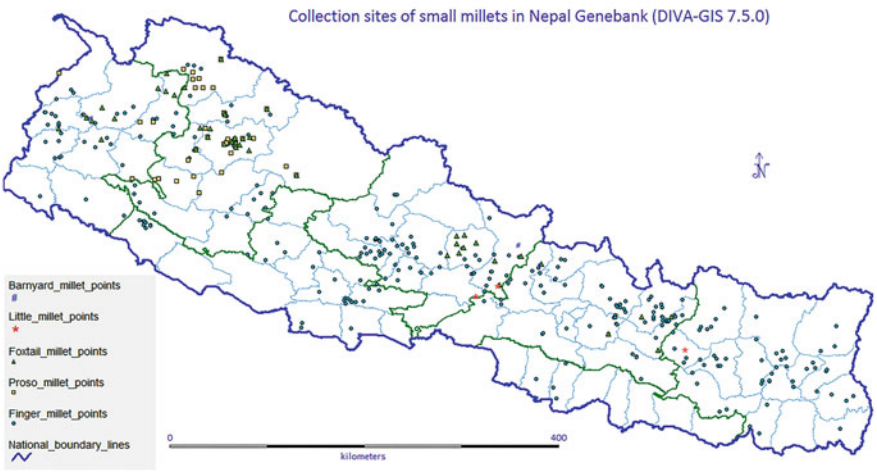

Fig. 2.3 Collection sites of finger millet accessions conserved in National Genebank, Nepal

finger millet accessions (1175 accessions) followed by foxtail millet (55 accessions) and proso millet (51 accessions) in medium and long-term conservation (Ghimire et al. 2017) (Table 2.3).

The geo-coordinates (latitudes and longitudes) of the collection sites of five small millet species have been plotted in the map of Nepal (Fig. 2.3). Finger millet accessions have been collected from far-east to far-west but we can still see the collection gaps from southern plane areas. The collections points for other four species are not distributed across the country. Future exploration and collection mission of Genebank need to be targeted in those gaps or unexplored areas.

2.3.4 In Situ and On-Farm Conservation

In situ conservation status of small millets has not been studied and documented properly but many wild relatives of *Echinochloa*, *Eleusine*, *Panicum*, *Paspalum,* and *Setaria* were reported in various in situ conservation sites (national parks, conservation areas, hunting reserves, wetlands, etc.) of Nepal as well as in semi-domesticated conditions alongside with the cultivated land (Table 2.2). However, these species are not being conserved purposefully but they are being used as forages for domestic and wild animals. Unlike wild species, cultivated species are being conserved on-farm either by individual custodian farmers (household Genebank) or with the collective efforts of the communities (community seed banks). There are more than 130 CSBs reported in the country (Joshi et al. 2018), one-third of them are actively involved in conservation of native crop diversity including landraces of small millets. However, exact number of small millets landraces under conservation in CSBs is not available.

2.4 Utilization Status

According to MoAD (2022), the average national productivity of finger millet since 31 years is roaming between 1.1 and 1.2 t/ha (Fig. 2.1). Available genetic resources have not been properly utilized in breeding programs. Research in the fourth important crop of the nation is not adequate and the situation is even far-below in other millets. Poor utilization of local landraces conserved in Genebank for the crop improvement program is due to either lack of information about the desirable accessions in the Genebank resulting from the poor characterization and evaluation data, or lack of skill manpower to use these landraces in breeding program as donors of desirable traits. In recent years, the demand of Genebank accessions is increasing slowly from scientists and students for research purpose.

2.4.1 Released Varieties

Number of released varieties is one of the indicators of utilization of any genetic resources. There are a total of eight varieties of small millets released officially by the National Seed Board for cultivation in Nepal, out of them, five are released varieties of finger millet and three are recently registered landraces, one each of finger millet, foxtail millet, and proso millet (Table 2.4). Among the eight in the table, the first two varieties Okhle-1 and Dalle-1 were released 42 years' ago.

2.4.2 Characterization and Pre-breeding

Only about 10% of genetic resources stored in Genebanks have been utilized in crop improvement program which mainly due to a lack of information about the desirable accessions in the Genebank resulting from the poor characterization and evaluation

Table 2.4 Details of finger millet varieties released in Nepal (Joshi et al. 2017; SQCC 2021)

Variety	Crop	Origin	Background	Released year	Major agro-morphological characters				Recommended domain
					Plant height (cm)	Days to maturity	Grain yield (t/ha)	Finger type	
Okhle-1	Finger millet	Nepal	Landrace from Okhaldhunga	1980	80	154–194	3.3	Compact	Mid to high hill
Dalle-1	Finger millet	India	IE-980	1980	110	125–151	3.3	Compact	Inner terai to mid hill
Kabre kodo-1	Finger millet	Nepal	Landrace from Surkhet	1990	82	147	2.3	Erect	Mid hill (900–1900 m)
Kabre kodo-2	Finger millet	India	GE-5176	2015	91	153	2.5	Open	Mid hill
Shailung kodo-1	Finger millet	India	GE-5016	2015	100	155	2.5	Compact	High hill (1500–2200 m)
Rato kodo	Finger millet	Nepal	Landrace from Jumla	2021	115	155	2.9	Compact	High hill (2000–3000 m)
Bariyo kaguno	Foxtail millet	Nepal	Landrace from Lamjung	2021	160	115–125	2.2	Compact drooping	Mid hill (900–1900 m)
Dudhe chino	Proso millet	Nepal	Landrace from Humla	2021	145	78–93	2.1	Drooping like rice	High hill (2000–3000 m)

Table 2.5 Number of small millets accessions characterized at the National Genebank, Khumaltar

Crop	Characterized accessions	Method	Diversity status	Reference
Finger millet	537	Morphological descriptors	High	Bhattarai et al. (2014)
	50	Morphological descriptors	High	Bastola et al. (2015)
	40	RAPD and SSR markers	High	Joshi et al. (2020b)
	300	Morphological descriptors	High	Ghimire et al. (2020)
Proso millet	44	Morphological descriptors	Low	Ghimire et al. (2018a)
Foxtail millet	44	Morphological descriptors	High	Ghimire et al. (2018b)

data (Nguyen and Norton 2020). A systematic study of collection, characterization, and evaluation of local millet landraces and introduced exotic varieties from Africa and India was carried out by Hill Crops Research Program (HCRP) after its establishment in 1972. During 1975–1995, more than 1000 accessions of different millet species were collected from various parts of the country and conserved at HCRP (Upreti 1995; Baniya et al. 2001). Unfortunately, those germplasm were lost due to firing of HCRP office building during political conflict period (Ghimire et al. 2017). After the establishment of Nepal Genebank in 2010, germplasm characterization of Nepalese small millet accessions has been restarted using agro-morphological descriptors. A total of 927 finger millet accessions and 44 accessions each of foxtail millet and proso millet have been characterized phenotypically (Table 2.5). A total of 300 Nepalese finger millet accessions collected from 55 districts of the country have been recently characterized at molecular level in International Crops Research Institute for Semi-Arid Tropics (ICRISAT) using genotyping by sequencing (GBS) approach but the result is not published yet.

2.4.3 Unique Genetic Resources

There are many landraces of different small millets with unique characters found in Nepal (Table 2.6). Landraces like Maal kaguno and Dhan kodo are unique and endangered but crops like barn yard millet, little millet and kodo millet etc. are endangered crops since farmers abandoned these crops to grow due to various factors such as lower yield, processing difficulty, high labor demanding, and rice food culture.

Table 2.6 Some unique landraces of small millets with their characteristics (Ghimire et al. 2017)

Crop	Landrace name	Distribution	Unique/ endangered	Characteristic features
Finger millet	Samdhi kodo	Scattered in small areas of lower hills	Endangered	White color seeds, white color porridge, prestigious due to color
Finger millet	Paaundur kodo	Rarely found in lower hills	Endangered	Adapted to spring season cultivation, drought tolerant, good in back pain for human and animals
Finger millet	Raato kodo	Localized in Jumla	Unique	Red color seeds, early maturing, adapted to high altitudes (>2000 m)
Finger millet	Asoje kodo	Scattered in eastern hills	Unique	High yielding, early maturity
Finger millet	Nangkatuwaa kodo	Scattered in central and western hills	Unique	High yielding, easy picking with nails
Foxtail millet	Aule kaaguno	Localized in Jumla	Unique	Typical finger-like branching at the tip of panicles
Foxtail millet	Bariyo kaaguno	Localized in Lamjung	Unique	High yielding, attractive panicles, early maturing
Foxtail millet	Maal kaaguno	Localized in Gorkha	Endangered	Medicinal value, good for lactating animals, effective in mastitis control
Foxtail millet	Kaalo kaaguno	Localized in Humla	Unique	Black color grains, medicinal value, drought tolerant
Proso millet	Dudhe chino	Localized in Humla	Unique	High yielding, drought tolerant, white color seeds
Proso millet	Haade chino	Localized in Humla	Unique	Good taste, drought tolerant, red color seeds
Barn yard millet	Saamaa	Rarely found in mid hills	Endangered	Considered as holy grains, consumed in fasting as fruits, difficult for processing
Little millet	Dhaan kodo	Rarely found in mid hills	Endangered	Drought tolerant, small oval seeds with shiny brown color

2.5 Promotional Initiatives

We have discussed that small millets are in low priority of the nation compared to major food crops. However, finger millet is getting significant attention from both government and non-government sectors since five decades. Some initiatives from public and private sectors for the promotion of small millets in Nepal have been briefly discussed in this section.

2.5.1 Hill Crops Research Programme (HCRP)

Ministry of Agriculture Development established HCRP in Dolakha of eastern Nepal in 1972 with the research mandate of finger millet, buckwheat, barley, grain amaranth. Despite of inadequate human as well as financial resources, HCRP under the umbrella of Nepal Agricultural Research Council (NARC) is working as lead public institution for small millets research and released five finger millet varieties together with their quality seeds and package of practices.

2.5.2 National Agriculture Genetic Resources Centre (National Genebank)

Ministry of Agriculture Development established the National Genebank in Lalitpur in 2010 with the mandate of promoting conservation and use of agricultural biodiversity including small millets. Besides ex situ repository, the National Genebank has been working for characterization and pre-breeding, support farming communities for on-farm conservation and support the Government of Nepal for the development of enabling policy environment for agro-biodiversity conservation. The National Genebank has been collaborating with national non-government organization like Local Initiatives for Biodiversity Research and Development (LI-BIRD) and international organizations like Bioversity International, ICRISAT, etc. for the promotion of native crops including small millets and facilitate CSBs to register three landraces of small millets.

2.5.3 Millet Mission Program

The Department of Agriculture (DoA) launched Millet Mission Program in 24 hill districts from 2013 to promote small millet crops for food security of hill farmers. Collection of germplasm from project districts and submission in the National Genebank, distribution of quality seeds and processing machines to the farmers in subsidized rate, awareness creation programs including training on value chain and product diversification were the key activities of the program. Unfortunately, this mission is terminated due to the inadequacy of improved quality seeds and machines.

2.5.4 Native Crops and Organic Agriculture Promotion Program

The Centre for Crop Development and Agro-biodiversity Conservation (CCDABC) of DoA is running Native Crops Promotion Program and Organic Agriculture Promotion Program since 2018 in hill districts in collaboration with provincial and local governments. Both of these programs have small millets in their mandate crops.

2.5.5 Global Collaborative Projects (In-Situ, NUS, LCP)

The National Genebank-NARC, LI-BIRD, and Bioversity International have successfully implemented three important global projects namely In-Situ Conservation Project (1998–2006), Neglected and Underutilized Species (NUS) (2005–2009) and Local Crops Project (LCP) (2014–2019). All these projects prioritized small millets mainly finger millet, foxtail millet, and proso millet as their mandate crop. These projects were able to create awareness at local and national level, enhance potential landraces, deploy portfolio of varieties from Genebank to farming community, empower farmers and CSBs on variety and seed selection, processing, value addition, and product diversification.

2.6 Problems and Challenges

Although small millets are resilient to adverse environments, there are some biotic factors (neck and finger blast diseases in finger millet and stem borers and birds in proso and foxtail millet) and abiotic factors (drought, cold, etc.). There are some socio-cultural factors affecting small millets production such as rice-based food habit, detraction of youth population from small millets cultivation and consumption, youth migration, etc. Farmers are reluctant to grow small millets due to their low productivity per unit area, less profit, high labor demanding (finger millet), difficulties in processing (proso millet, barn yard millet, little millet), etc. Inadequate research on these crops to develop high yielding and disease resistant varieties leaving less varietal options to the millet growing farmers. Research on processing equipment, value addition, and product diversification is also limited. Lack of policy environments such as subsidy to farmers growing these crops also hindering the production of small millets in the country. Besides these challenges, there are great opportunities to promote these small millets as future smart foods.

2.7 Way Forward

- The National Genebank is holding thousands of accessions of different small millet species; however, there are still unexplored areas and landraces exists on-farm. Exploration of such areas with close collaboration with farmers, community seed banks, and local governments needs to be continued.
- There is an urgent need of safety duplication of collected accessions in international Genebanks like Global Seed Vault-Norway, ICRISAT-India, etc. so that we can repatriate them as and when needed.
- Most of the millet genetic resources conserved so far have not characterized so far at molecular level. There is an urgent need to characterize and sequence those accessions using high throughput DNA technology in collaboration with international institutes such as ICRISAT.

- The research mandate of small millets in Nepal is for HCRP of NARC. Since this station is not suitable for foxtail millet and proso millet, Agriculture Research Station (ARS) Jumla should be mandated for foxtail and proso millets while HCRP should be dedicated for finger millet.
- Increased research funding is necessary for institutional as well as researcher's capacity enhancement. Moreover, there is an urgency for the deployment of multidisciplinary team of scientists in HCRP and ARS Jumla without further delay.
- Nepalese farmers are facing the problem of improved and quality seed of small millets. Seed multiplication of promising and locally adapted landraces should be started through Community Seed Banks or farmers groups and mainstreamed as in major cereal crops.
- Conservation through utilization is the key for any genetic resources. To enhance the use of small millets in Nepal, awareness creation and promotional activities should be launched with improved processing technology, value addition, product diversification, and inclusion of small millets in national food and nutrition programs.

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