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CONSERVATION AND UTILIZATION OF SUMMER CROPS BIODIVERSITY IN NEPAL

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ABSTRACT

Nepal faces a pressing challenge with the alarming loss of around 50% of its summer crop genetic resources (SCGRs) and the endangerment of native landraces. To combat this decline, the national genebank in Nepal has developed 101 good practices for agricultural genetic resources (AGRs) conservation and utilization. Red zoning and red listing strategies aid in identifying conservation priorities. The Genebank collaborates with stakeholders to collect, characterize, and promote SCGRs, resulting in 6177 accessions representing 71 summer crop species stored in Seed Banks. Diverse conservation repositories include genebanks, tissue banks, DNA banks, community genebanks, school field genebanks, and agro-gene sanctuaries. In 2022, 724 accessions of 20 summer crops were distributed for research, while the registration of 19 landraces after genetic enhancements led to their inclusion under the National Seed Board. The free distribution of germplasm accelerates its utilization, further facilitated by online access. The genebank also promotes agro-insect field genebanks recognizing the importance of agro-insects and pollinators in biodiversity conservation. To maintain native SCGRs, value additions are emphasized, underlining the need to actively enhance genetic diversity in agricultural fields. These comprehensive measures underscore Nepal's commitment to safeguarding agrobiodiversity, ensuring food security, and bolstering agricultural resilience to climate and other stresses.

Keywords: Agronomic summer crop, Conservation, Database, Forage summer crop, Horticultural summer crop

1. INTRODUCTION

Nepal stands as a rich reservoir of agrobiodiversity, with its economic underpinnings deeply intertwined with the products and services drawn from these abundant resources (Gotame et al., 2019; Joshi et al., 2020, 2023; Ghimire et al., 2022; NAGRC, 2023). This diversity is a product of a complex interplay of factors, encompassing diverse agro-climatic zones, intricate farming systems, a tapestry of ethnicities, varying socioeconomic landscapes, substantial altitudinal variations, and the challenges posed by intricate topography. This intricate tapestry has given rise to numerous micro-niches, nurturing an extensive tapestry of agricultural diversity across the nation. The role of agrobiodiversity transcends conventional boundaries, permeating various agricultural disciplines, such as plant breeding, pathology, agronomy, entomology, and food science. It serves as a versatile solution to an array of agricultural challenges, including those stemming from environmental pressures and the specter of climate change. These resources serve as the foundational elements for genetic improvements and remain indispensable for upholding global food production systems.

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Their sustained availability represents a fundamental prerequisite for realizing heightened productivity and nutritional value. Safeguarding extant genetic diversity is pivotal for ensuring the sustainability of agriculture, and facilitating access to agricultural researchers, breeders, and farmers is equally crucial. The genebank's repository of Agricultural Genetic Resources (AGRs) serves diverse purposes, from securing long-term preservation to direct application in agricultural production, environment preservation, scientific experimentation, genetic enhancements, contributions to sustainable breeding, and material repatriation (NAGRC, 2022).

However, over the past forty years, the drive to modernize and commercialize agriculture has cast a shadow over traditional AGRs and indigenous knowledge, skills, and technologies. This transformation has had far-reaching consequences, including the depletion of ecosystems and the erosion of diversity. Climate change exacerbates these challenges. One of the significant drivers of this genetic erosion is the replacement of diverse farmers' varieties with modern alternatives. Alarmingly, more than 75% of global crop diversity vanished irrevocably during the 20th century (FAO, 1999).

Acknowledging the pivotal significance of conserving and sustainably exploiting agrobiodiversity for national development and to meet international obligations, such as the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the Government of Nepal, in partnership with the Nepal Agricultural Research Council (NARC), established the National Agriculture Genetic Resources Center (NAGRC, commonly known as Genebank) in 2010 in Khumaltar (NAGRC, 2023; Joshi et al., 2020). This monumental establishment, situated at an altitude of 1368 meters (27°40'N, 85°20'E), is dedicated to conserving and sustainably utilizing AGRs, ensuring the availability of invaluable genetic assets for the nation's prosperity. The Genebank comprises five integral units: Collection and Distribution, Conservation, Characterization and Evaluation, Biotechnology, and Documentation, Publication, and Training. These collaborative efforts have yielded substantial achievements in the management of agrobiodiversity and some major milestones are given in Table 1 (Joshi, 2017).

Table 1. Historical movement on conservation of agricultural genetic resources in Nepal

Year	Milestone
1984	Establishment of Plant Genetic Resource Section in Agriculture Botany Division of NARC
1986	Establishment of medium-term ex-situ conservation
2010	Establishment of National Genebank (NAGRC)
2012	Establishment of Field Genebank and Community Field Genebank
2013	Initiation of Tissue Bank and DNA Bank
2014	Establishment of Base Collection Room of 100,000 accessions capacity with -18^{o}C for long-term seed conservation (50-100 years)
2015	Establishment of Potato Park, Sugarcane Park, Ginger and Turmeric Park
2016	Establishment of short-term storage for vegetatively propagated and recalcitrant crops
2016	Establishment of Aqua Pond Genebank
2018	Establishment of Agro Gene Sanctuary

Source: Joshi (2017)

Agrobiodiversity is an integral facet of overall biodiversity, encompassing six primary categories and four subcategories, as depicted in Figure 1 (Joshi et al., 2020). Given its pivotal role in agricultural research and education, in addition to its contributions to food security, nutrition, business, health, and environmental sustainability and enhancement, the preservation of agrobiodiversity takes on paramount importance. However, the incursion of agricultural modernization has, regrettably, led to the erosion of numerous native and local agrobiodiversity components, placing many more on the brink of extinction (Joshi et al., 2020). It is imperative to undertake measures for the conservation of these invaluable resources to ensure their long-term availability, proper utilization, database management, comprehensive characterization, and the enhancement of their genetic performance. For reference, Table 2 provides a list of various summer crops (excluding forage crops).

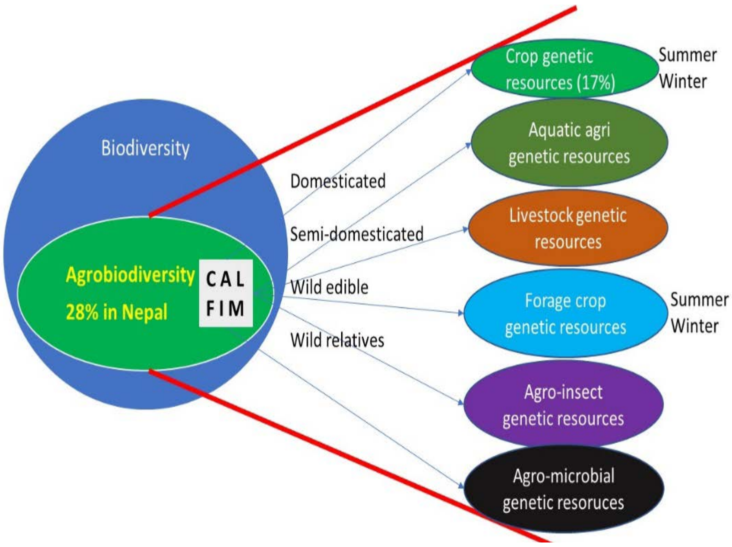

Figure 1. Components and sub components of agrobiodiversity (CALFIM: crop, aquatic agricultural genetic resource, livestock, forage, agro insect and agro microbe)

Source: Joshi et al. (2020)

This paper comprehensively covers the National Genebank's achievements over the past two years with a focus on summer crops. Its principal objectives include disseminating information about the conservation and preliminary research status of summer crops, promoting knowledge about best practices for the conservation and utilization of AGRs, and shedding light on matters and strategies concerning agrobiodiversity.

2. METHODOLOGY

In our research, a multifaceted methodology was employed to comprehensively investigate summer crop agrobiodiversity conservation. This methodology encompassed an extensive review of relevant literature, enabling us to synthesize existing knowledge and insights. Additionally, we conducted in-depth analyses of databases such as Genesys (https://www.genesys-pgr.org/, the NAGRC web portal (https://genebank.narc.gov.np/), and Joshi et al. (2023), thus incorporating the latest data and research findings. Furthermore, we embarked on fieldwork, exploring and visiting diverse summer crop areas to collect germplasm while simultaneously gathering essential passport and general information. To ensure a wellrounded perspective, we organized focused group discussions in all seven provinces, which enabled the collection of information on diversity, conservation status, impact, and pertinent issues and challenges. Lastly, interaction with key experts in the field was undertaken to verify and enrich the information gathered from both fieldwork and the literature, culminating in a robust and comprehensive research approach.

3. RESULTS AND DISCUSSION

3.1 SUMMER CROPS, CLASSIFICATION AND NATIONAL PRIORITY ISSUES

The National Genebank classifies crop genetic resources (CGRs) into two primary categories based on their growing season and economic utility: summer crops and winter crops. Summer crops are those cultivated during the warm or hot seasons, and the further classification of summer crops is illustrated in Figure 2. This paper specifically addresses the conservation status of these distinct summer crop groups.

Table 2. Lists of summer crops (agronomic and horticultural crops)

English Name	Nepali Name	English Name	Nepali Name	English Name	Nepali Name
-	Bayar	Cucumber	Kaankro	Perilla	Silaam
-	Haade Bayar	Custard apple	Seetaaphal or Sarifaa	Peruvian ground apple, Yakon	Bhui Shyau
-	Ban timilo	Double Bean	Asaare simi	Pigeon pea	Rahar
-	Harro	Drumstick	Sajiwan, Sital Chini	Pineapple	Bhuikatahar
-	Jamun	Elephant foot yam	Ole	Pointed Gourd	Parbal
Amaranth (grain)	Latte	Fig	Nivaaro	Proso Millet	Chino
Amaranth (Red)	Latte	Finger millet	Kodo	Pumpkin	Farshi
Amaranthus	Latte, Marshe, Lude	Foxtail Millet	Kaaguno	Rice	Dhaan
Arabica coffee	Coffee	French bean	Ghui Simi, Daal simi, Asaare simi	Ridge Gourd	Paate Ghiraulaa
Ash Gourd, Wax Gourd	Kuvindo	Ginger	Aaduwa	Robusta coffee	Coffee
Balsam Apple	Barelaa	Greater Yam, White	Tarul, Ghar	Rose apple	Gulaab-Jaamun
Banana	Keraa	Groundnut/ Peanut	Badaam	Sesame	Til
Barnyard Millet	Saamaa	Guava	Ambaa, Belauti	Sesbania	Dhainchaa
Butter tree	Chiuri	Hot Pepper	Piro Khursaani	Snake Gourd	Chichindo
Bead plum	Haade bayar	Jute	Paat	Sorghum/Great millet	Junelo

English Name	Nepali Name	English Name	Nepali Name	English Name	Nepali Name
Bean, French Bean, Kidney bean	Simi	Kodo millet	Kodi	Soybean	Bhattamaas
Bell (Sweet) Pepper	Bhede Khursaani	Kumquat	Muntalaa	Sponge Gourd	Ghiraulaa
Bitter Gourd	Tite karelaa	Large/ greater Cardamom	Alaichi	Summer squash	Deshi pharsi
Black Pepper, Pepper	Marich	Little millet	Dhan kodo, Kutki	Sunflower	Surya mukhi
Blackgram	Maas	Long Pepper	Pipalaa	Sunhemp	Sanai
Bottle Gourd	Laukaa	Maize	Makai	Sweet potato	Sakharkhanda
Cassava, Tapioca	Simaltarul	Mango	Aamp	Tamarind	Emli
Ceylon oak	Kusum	Mint (Field, Garden)	Pudinaa	Taro	Pidaalu
Chayote	Iskush	Monkey Jack	Badahar	Thin shelled walnut	Daante Okhar
Chilly	Khursaani	Mungbean	Mung maas	Tobacco	Surti
Cinnamon	Daalchini	Nepali Sumac	Sati bayar	Turmeric	Besaar
Cinnamon, Bay Leaf, cassia	Tejpatta	Niger	Philingo, Jhuse Til	Water Cress	Simsaag
Cotton	Kapaash	Okra	Bhindi	Wood apple	Bael
Cowpea	Bodi	Paspalum	Kodi	Yam	Tarul
		Pearl Millet	Ghonge	Zigyphus	Jangali bayar

Source: Gotame et al. (2019), Joshi and Shrestha (2017), Joshi et al. (2023) and NAGRC (2023)

National priority issues for the conservation and utilization of summer crops revolve around safeguarding AGRs to ensure their availability for future generations. These priorities encompass various critical aspects. The first priority involves the conservation of a diverse array of crop varieties. Preserving a wide range of crop varieties is essential to maintain genetic diversity, enabling crops to adapt to changing environmental conditions and evolving agricultural needs. Promoting native and local AGRs is the second key issue. Encouraging the sustainable cultivation of these varieties not only supports traditional agricultural practices but also maintains genetic diversity. This, in turn, enhances the resilience of crops to local conditions and market demands. Establishing conservation banks, including seed banks and genebanks, is the third priority. These banks serve as repositories for diverse crop varieties, ensuring their availability for research and breeding programs, thus safeguarding their genetic potential.

The development of a comprehensive online database is the fourth priority. This digital resource provides valuable information on genetic resources and their characteristics, facilitating research, breeding, and conservation efforts, while enhancing accessibility. The fifth priority involves red zoning and red listing. These efforts aim to identify danger regions/

vulnerable areas with high genetic diversity (red zones) and those species/ landraces facing threats (red listing). The objective is to rescue and conserve endangered germplasm, thereby preventing their loss.

On-farm research and breeding programs constitute the sixth priority. Collaborative initiatives involving farmers directly enhance the genetic traits of AGRs, ensuring they are better suited to local conditions and market demands. The seventh priority focuses on policymaking, guidelines, and capacity development. The formulation of clear policies and guidelines supports and regulates AGR-related activities, promoting sustainable practices and research. Moreover, capacity development is essential to equip a skilled workforce capable of implementing effective conservation and utilization strategies.

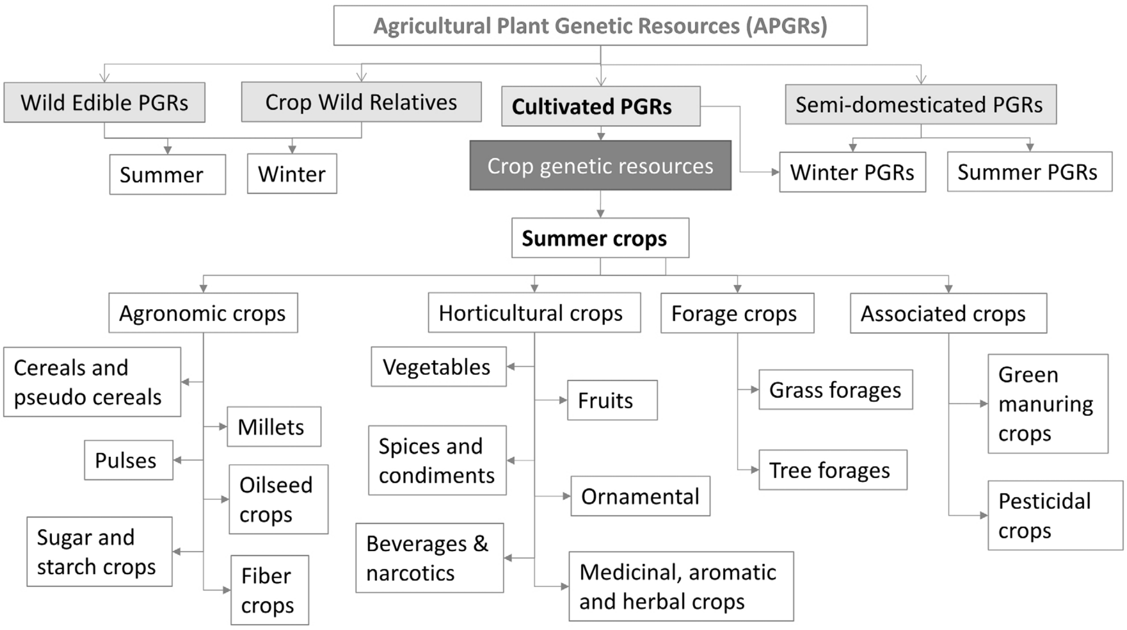

Figure 2. Classification and coverage of summer crops

Source: Joshi and Shrestha (2017)

3.2 CONSERVATION STATUS OF SUMMER CROP GENETIC RESOURCES

Collection

The routine activities of the genebank encompass the exploration and collection of agricultural plant genetic resources. In the past two years, a total of 1,033 samples representing 93 different food crop species were gathered from 17 districts.

Conservation

Over the specified period, 1,207 accessions of 12 different crops were regenerated and seed increased at Khumaltar, encompassing 1,003 accessions of six agronomic crops and 204 accessions of six horticultural crops. Furthermore, seed samples from 2,027 accessions belonging to 55 crop species were meticulously cleaned and subjected to germination testing. In addition, seed from 820 accessions of 39 different crop species were incorporated as new entries within active and base collections. A field genebank spanning an area of 1,500 square meters was established for vegetatively propagated crops and those with recalcitrant seeds. Various recalcitrant species, such as 86 accessions of turmeric, 55 accessions of taro, 49 accessions of garlic, and 21 perennial species were collected from diverse locations and are now maintained within the Khumal field genebank. Approximately 96 accessions representing five crops, including potato, sweet potato, sugarcane, banana and large cardamom, are preserved in the Tissue Bank. The selection of blast-resistant rice lines was accomplished utilizing nine SSR markers from a pool of 90 accessions. Furthermore, the diversity of 35 maize accessions was assessed, with DNA samples from 48 chilly accessions and 92 amaranth accessions preserved in the DNA bank. Collaborative initiatives were initiated with 11 different community organizations, with agreements to work together on-farm agrobiodiversity conservation. A comprehensive breakdown of summer crop conservation is provided in Table 3.

Characterization, evaluation and pre-breeding

The genebank's efforts encompassed the characterization and evaluation of a total of 1,397 accessions representing 17 different crops, including 1,005 accessions from six agronomic crops (rice, maize, foxtail millet, finger millet, and soybean) and 392 accessions from 11 diverse horticultural crops. This was carried out using descriptors developed by institutions such as IPGRI and other international bodies. Notably, 15 elite lines from five crops (comprising 2 each of okra and cucumber, 1 Anadi rice, and 5 each of finger millet and foxtail millet) were identified through pre-breeding, as documented in various research publications (Ghimire et al., 2022; Karkee et al., 2021; Thapa et al., 2022; NAGRC, 2022, 2023).

Database management

Passport data for all newly acquired collections and accessions conserved across short, medium, and long-term storage are diligently maintained and updated. Additionally, passport data from previous collections is also kept current. Presently, the genebank houses and preserves 10,084 crop varieties (including both summer and winter) along with their respective passport data.

Germplasm distribution

An essential objective of germplasm conservation within the genebank is to facilitate the utilization of this genetic material in plant breeding and related research activities. In the year 2022, seeds from 724 landraces representing 20 summer crops were distributed to students, NGOs, breeders, and farmers for research and sustainable germplasm utilization (as illustrated in Figure 3). It is essential to note that seed distribution occurs exclusively from the active collections. Additionally, diversity kits, which include pre-breeding lines (elite lines), site-specific best landraces, unique landraces, pre-release lines, and released varieties, were provided to various farmers during exploration and collection missions. It's important to note that seed distribution occurs exclusively from the active collections.

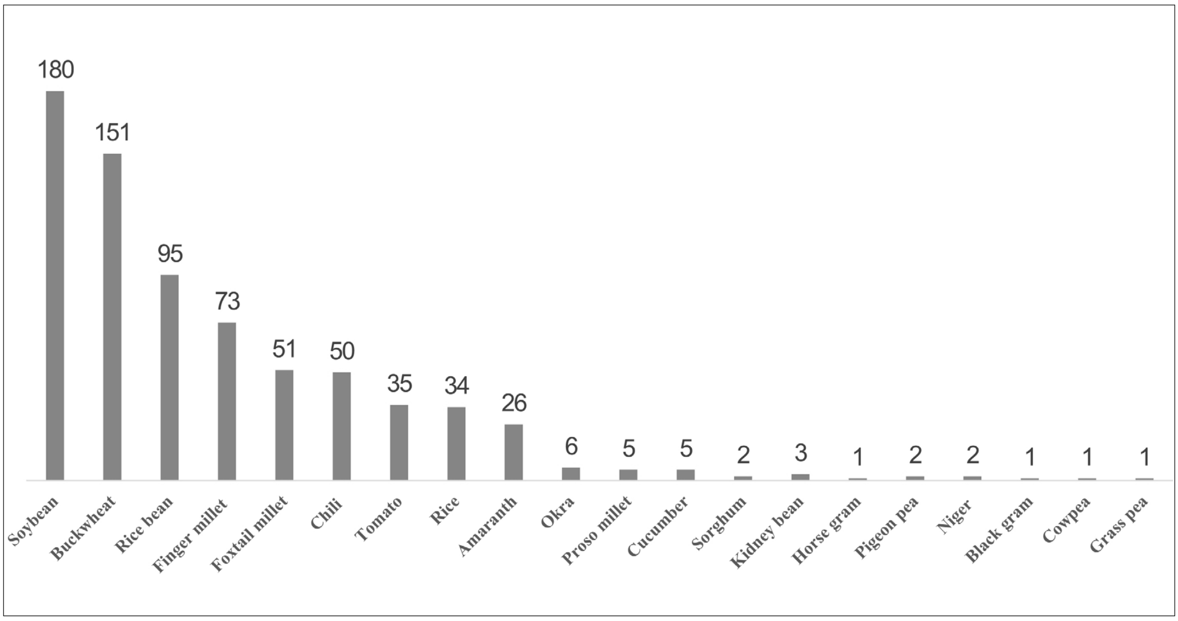

Figure 3. Number of accessions of summer crops distributed in 2022

Table 3. Total number of accessions of summer crops conserved in medium term at National Genebank, Khumaltar

Crop	Scientific name	नेपाली नाम	Accessions, n
Cereals	अन्नबालीहरु		
Maize	Zea mays L.	मकै	762
Rice, paddy	Oryza sativa L.	धान	2437
Pseudo-cereals	छद्म अन्नबालीहरु		
Amaranth	Amaranthus spp. (4 species)	लट्टे, मार्से	274
Common Buckwheat	Fagopyrum esculentum Moench.	मिठे फापर	136
Tartary Buckwheat	Fagopyrum tataricum L. Gaertn.	तिते फापर	173
Millets	कोदो जन्य बालीहरु		
Barnyard Millet	Echinochloafrum entacea Link.	सामा	4
Finger Millet	Eluesine corocana L. Gaertn.	कोदो	1055
Foxtail Millet	SetariaitalicaL. Beauv.	कागुनो	46
Little Millet	Panicum sumatrense Roth.	कुट्किक, धान कोदो	1
Proso Millet	Panicum miliaceum L.	चीनु	43
Sorghum	Sorghum biclor L.	जुनेलो	6
Pulses	दलहन बालीहरु		
Adjuki Bean	Vigna angularis Ohwi & Ohashi	मास लहरी	1
Bean, French Bean	Phaseolus vulgaris L.	सिमी	268
Black Gram	Vigna mungo L.	मास	45
Cowpea	Vigna unguiculata L.	बोडी	33
Grass Pea	Lathyrus sativus L.	खेसरी	106
Green Gram, Mung Bean	Vigna radiata L.	मुंग, हरियो मास	9
Horse Gram	Dolichos biflorus Roxb.	गहत	42

Crop	Scientific name	नेपाली नाम	Accessions, n
Pigeon Pea	Cajanus cajan L.Huth.	रहर	12
Rice Bean	Vigna umbellate Thung. Ohwi&Ohashi	मस्यांग, सिल्टुङ	113
Soybean	Glycine max L. Merr.	भटमास	155
Oilseed Crops	तेल बालीहरु		
Groundnut	Arachis hypogaea L.	बदाम	5
Niger	Guizotia abyssinica L. Cross	फिलिंगे, झुसेतिल	11
Perilla	Perilla frutescens L.	सिलाम, तिल्खुरो	15
Sesame	Seasamum indicum L.	तिल	25
Sunflower	Helianthus annuus L.	सुर्यमूखी	1
Vegetables	तरकारी बालीहरु		
Balsam Apple	Momordica balsamina L.	बरेला, करेला, चुच्चे करेला	8
Bitter Gourd	Momordica charantia L.	तिते करेला, करेला	1
Bottle gourd	Lagenaria siceraria	लौका	4
Brinjal, Egg Plant	Solanum melongena L.	भण्टा	33
Cucumber	Cucumus sativus L.	काँक्रो	55
Sponge gourd	Luffa aegyptiace	घिरौला	47
Tomato	Solanum lycopersicum	गोलभेंडा	18
Lettuce	Brassica japonica Thb. Sieb	जिरिको साग	1
Okra, Lady's Finger	Abelmoschus eschulentusL. Moench.	भिण्डी, रामतोरिया	71
Pumpkin	Cucurbita moschata Duchesne.	फर्सि, कद्दु	10
Spine Gourd	Momordica dioica Roxb.	चटेल, झुसे करेला	1
Fruits	फलफूल बालीहरु		
Indian Plum	Zizyphus jujube Mill.	वयर	1
Pomegranate	Punica granatum	अनार	1
Spices	मसला बालीहरु		
Chilli pepper	Capsicum frutescens L.	खुर्सानी	69
Large Cardamom	Amomum subulatum Roxb.	अलैंची	5
Fibers	रेसा बालीहरु		
Hemp	Cannabis sativa L.	भाङ्ग, गाँजा	3
Jute	Corchorus olitorius L.	जुट	6
Forages	घाँसे बालीहरु		
Teosinte Grass	Zea perennis L.	टियोसिन्टे घाँस	1
Crop Wild Relatives	About 20 species	बालीका जंगली नातेदारहरु	50
Others	About 4 species	अन्य	14
Total	**71 species**		6177

3.3 RESEARCHABLE ISSUES AND ACTIVITIES

Researchable issues and activities within the domain of conservation and utilization of summer crops encompass a diverse array of critical concerns and ongoing research efforts. These issues serve as focal points for advancing the knowledge and practices associated with agricultural biodiversity. Major research issues include the development of site-specific crop varieties, the promotion of genetic diversity and the cultivation of polymorphic populations in agricultural fields. Additionally, research activities center around conservation through utilization and product diversification, embracing both static and dynamic conservation approaches and methods. A significant aspect involves enhancing the value of summer crops through breeding and non-breeding methods. The exploration of the potential of summer crop genetic resources is another central research concern. Moreover, mechanisms for safeguarding these resources and establishing links between agrobiodiversity and education, research, nutrition, environment, food, business, and health are integral to the research landscape. Research efforts also address the impact of climate change on summer crops, along with the management of online databases, and the documentation and profiling of these crops, including phenotypic, genotypic, and metabolite aspects. Genetic enhancement, fingerprinting, and the quantification of agrobiodiversity from various angles are also subjects of investigation (Joshi, 2021a).

Research activities are actively pursued within the framework of the Conservation and Utilization of Agricultural Biodiversity (CUAB) project. First part, dedicated to the conservation and utilization of agricultural plant genetic resources (CUAPGR), encompasses a wide array of activities aimed at preserving and enhancing the genetic diversity of agricultural crops. These activities include the exploration, collection, and distribution of germplasm. Seed cleaning, testing, and characterization ensure the quality and viability of the genetic material, while the processing and conservation of seeds in medium- and long-term storage facilities safeguard their long-term availability. The management and reinforcement of various conservation facilities, including the Field Genebank, Agro Gene Sanctuary, Raithane Nursery, and Herbal Conservation Garden, play a crucial role. Regeneration, multiplication, and characterization efforts extend to both agronomic and horticultural crops. Evaluation and pre-breeding activities enhance the genetic potential of these crops, while maintenance efforts focus on rare, unique, non-utilized, farmer-selected, and elite genetic resources. In-vitro conservation is employed for vegetatively propagated and recalcitrant seed crops, and molecular markers aid in the management of agricultural biodiversity. On-farm and in-situ conservation strategies are applied, while documentation and database management ensure the organized storage of critical information. The compilation of a national priority inventory encompasses neglected, underutilized, and wild plant species.

Second part, known as the management of aquatic, livestock, insect, and microbial agricultural genetic resources (MALIM-AGR), addresses diverse aspects. These include updating conservation strategies for aquatic, livestock, insect, and microbial resources, conducting feasibility studies for a mushroom park, establishing an aqua-pond genebank within the Genebank complex, and monitoring the wild bee population's role in ecological services and agricultural production.

Within this comprehensive research framework, multiple projects are actively contributing to the advancement of knowledge and practices. These projects include the Evolutionary Plant Breeding Project, which focuses on leveraging genetic diversity and evolutionary plant breeding to enhance farmer resilience to climate change, sustainable crop productivity, and nutrition under rainfed conditions. The Rebuilding Local Seed System Project centers on the collection, conservation, and repatriation of native crop seeds in earthquake-affected areas of Nepal. The Local Crop Project aims to integrate traditional crop genetic diversity into technology to buffer against unpredictable environmental changes in the Nepal Himalayas. Lastly, the Indigenous Seed System Project is geared towards improving seed systems to enhance food security for smallholder farmers in Nepal.

3.4 GOOD PRACTICES FOR CONSERVATION OF SUMMER CROPS BIODIVERSITY

National Genebank has implemented a comprehensive array of good practices, totaling 101 in number (Joshi, 2022; Joshi et al., 2020), and many of them are for summer crop biodiversity conservation and utilization (Figure 4). Many of these practices were developed in-house by National Genebank and include the establishment of various conservation banks. Notably, over 100 elite lines of summer crop genetic resources have been identified and shared with farmers, research institutions, and other organizations. A significant achievement is the registration of 19 improved landraces from 8 different crops, facilitating their recognition and protection. This registration process, involving landraces with diverse genetic characteristics, has been formalized through the creation of Schedule D in seed regulation, accompanied by the development of technical guidelines. Consequently, numerous landraces and varieties have been successfully registered under this provision. Some of conservation banks are given in Table 4.

Table 4. Conservation banks for summer crop genetic resources in Nepal

Agro gene sanctuary	**Cryo bank**	**Safety backup**
Agrobiodiversity trail	DNA bank	Safety duplication (black box)
Agro-insect field genebank	Field genebank	School aqua pond genebank
Agro-insect genebank	Forage field genebank	School field genebank
Agro-microbial field genebank	Gaushaalaa	School insect field genebank
Agro-microbial genebank	Herbal conservation garden	School mushroom park
Aqua pond genebank	Heritage site	Seed bank
Botanical garden	Household field genebank	Temple garden, holy garden
City park	Household genebank	Tissue bank
Community aqua pond genebank	Household insect field genebank	Village level community agro insect field genebank
Community field genebank	Household seed bank	Village level community aqua pond genebank
Community forestry	Livestock farm genebank	Village level community genebank
Community genebank	Mushroom park	Village level community field genebank
Community river	Office garden, agro-garden	Village level community livestock farm genebank
Community seed bank	Pollen and organ bank	Village level community seed bank
Conservation village	Protected area	Zoo
Crop specific park	Ramsar site	

In the realm of climate resilience, innovative technologies have been developed, encompassing climate-smart breeding and germplasm enhancement using a climate analog tool, cultivar mixtures, and evolutionary plant populations. Community-based initiatives, such as community seed banks, community field genebanks, and community aqua pond genebanks, have been established to further enhance genetic resources. The genetic improvement of landraces, landrace registration techniques, geographical indication, diversity blocks, diversity fairs, diversity field schools, and pre-breeding programs for the identification of dynamic elite lines have also been instrumental in this regard. Moreover, product diversification strategies have been devised for neglected and underutilized crops, aimed at encouraging conservation through utilization. A notable example is the development of Chino Kutak, a method designed in collaboration with the National Agricultural Engineering Research Center to simplify the processing of proso millet.

Furthermore, National Genebank has made ex-situ materials accessible through online databases, allowing easy searches to identify suitable germplasm. To raise awareness and promote the significance of native AGRs, various occasions have been designated, including the celebration of events such as the National Agrobiodiversity Year, National Agrobiodiversity Week and Day, Agricultural Genetic Resources Conservation Day, and National Genebank Day. These festivities are embraced and commemorated by numerous organizations across the country, further contributing to the conservation and appreciation of agrobiodiversity.

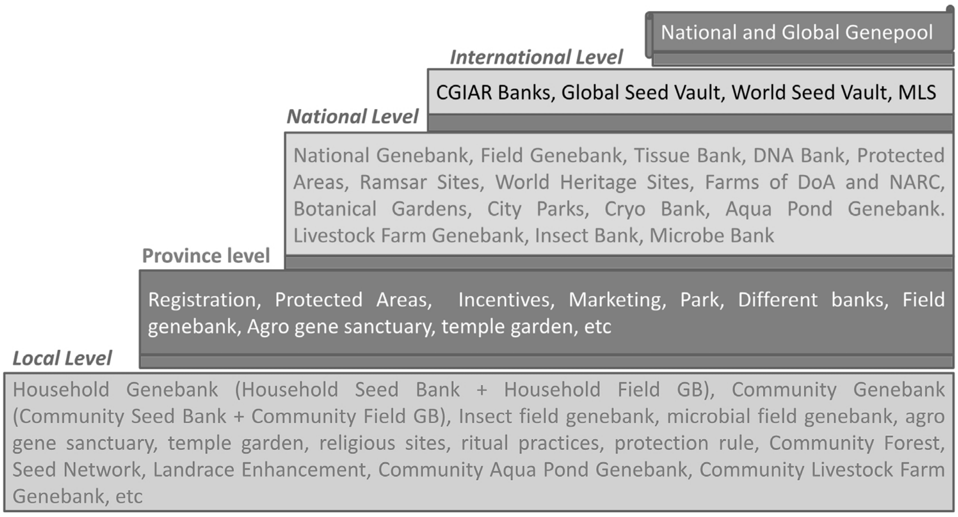

Figure 4. Governance based strategy and methods (good practices & actions) for better management of agrobiodiversity

Source: Joshi et al. (2020), Joshi (2022)

3.5 CURRENT CONSERVATION TECHNOLOGY ADOPTION IN THE NATION

The NAGRC has successfully developed numerous technologies, many of which have been widely embraced throughout the country. Some of these technologies are tailored to specific geographical locations and have found strong acceptance within their designated environments. The online accessibility of germplasm, genetic diversity information, and related data has proven highly valuable, with a substantial number of researchers, students, and farmers utilizing this extensive database. A broad spectrum of stakeholders, including non-governmental organizations (NGOs), international non-governmental organizations (INGOs), government agencies (GOs), farming communities, community-based organizations (CBOs), and private individuals, has actively adopted the technologies generated and pioneered by the National Genebank. Furthermore, select technologies have garnered international recognition and uptake. It is noteworthy that all three tiers of government in Nepal have also integrated specific technologies into their mainstream operations, attesting to the widespread impact and applicability of these innovations.

3.6 ENHANCING CONSERVATION TECHNOLOGY ADOPTION AND ADDRESSING RESEARCH GAPS

Many technologies, such as the Field Genebank, Landrace Registration, Community Seed Bank, and the Promotion of Native and Local Genetic Resources, have been widely embraced and integrated across various regions. However, the adoption of certain technologies has been hindered by factors such as limited awareness and capacity, the development of location-specific solutions, insufficient prioritization by key stakeholders, absence of supportive policies, inadequate investment, and a lack of promotional efforts. Identifying and addressing these barriers is vital in promoting wider technology adoption and ensuring their successful implementation.

Research on native and local summer crop genetic resources remains significantly underexplored. A noteworthy research gap is evident in both basic and applied action research aimed at enhancing the competence of native germplasm. Additionally, areas such as pre-breeding, the utilization of molecular markers, the creation and utilization of searchable databases, nutritional assessments, the amplification of ecological services, the assessment of genetic diversity's impact in agricultural fields, geographical indication strategies, use values, and product diversification all present notable research gaps. Closing these knowledge gaps is pivotal in advancing our understanding of summer crop genetic resources and fostering their sustainable utilization and conservation.

3.7 CHALLENGES IN THE EFFECTIVE EXTENSION OF DEVELOPED TECHNOLOGIES

The National Genebank is at the forefront of technology development related to the conservation and utilization of germplasm. However, several critical issues have hindered the efficient dissemination of these technologies. One of the primary challenges is the insufficient capacity in conservation sciences among stakeholders, limiting their ability to effectively promote and utilize these advancements. Native and local agrobiodiversity has often received low priority, further impeding their widespread adoption. Some technologies, despite their significance, do not yield immediate, tangible benefits, which has curtailed their extension efforts. On the positive side, site-specific germplasm-based technologies developed by the Genebank have demonstrated success in their target locations. Nonetheless, the absence of a searchable database, containing essential germplasm characteristics, remains a significant hurdle for the extensive utilization of ex-situ materials in research, production, and education.

Key problems and challenges include the lack of a web portal and passport application, difficulties encountered in regenerating and multiplying various crops and plants in Khumaltar, limited screening environments, incomplete adaptation of the accessioning system nationwide, the absence of essential legislation and guiding documents, including the Agrobiodiversity Act and relevant policies, as well as the inadequate allocation of in-situ sites for agrobiodiversity. The absence of an emergency fund for urgent maintenance work, poorly managed and inaccessible databases, and the yet-to-be-initiated DOI and DNA barcoding are additional issues. The underutilization of conserved germplasm, insufficiencies in budget allocation, staffing, and the establishment of a cryo bank, inadequacies in mechanization, and the neglect of conservation efforts for aquatic, livestock, insects, microorganisms, and forage AGRs are also significant problems. The conservation of agrobiodiversity, despite its paramount importance, often lacks priority, and many good practices related to its conservation have not been integrated into mainstream agricultural practices. The overreliance on foreign germplasm, limited utilization of germplasm under the ITPGRFA - Multilateral System, genetic erosion in AGRs, issues related to identification and duplicates, and the ineffective functioning of intellectual property rights within AGRs compound the challenges. Furthermore, the uncertain market for native products and the need for more insect, microbe, and bird-friendly production and research areas add to the complex landscape of issues facing the National Genebank's conservation and utilization efforts.

4. CONCLUSION

Many of the summer crop genetic resources (SCGRs) remain under the threat of being lost from agricultural fields. The prevalent practice of monocropping should be revised, and farming methods that promote genetic diversity should be encouraged. Relevant stakeholders should adopt both static and dynamic conservation strategies to ensure the preservation of these resources. Prioritizing the implementation of various good practices, of which 101 good practices have already been identified, is crucial for the long-term conservation and sustainable utilization of SCGRs. Notable among these practices are the establishment of a Field Genebank, Aqua Pond Genebank, Agro-Insect Field Genebank, Evolutionary Crop Population, Forage Field Genebank, Agro Gene Sanctuary, *Raithane* Nursery, School Field Genebank, and Herbal Conservation Garden. Essential routine tasks, such as documentation, germplasm and passport collections, characterization, and database management, should be diligently continued. Red zoning and red listing of SCGRs play a pivotal role in prioritizing and taking action for the conservation of endangered germplasm. Moreover, the collected germplasm has been underutilized in research and education, emphasizing the need to develop site-specific varieties that can compete on a global scale. Effective collaboration among local, provincial, and national-level organizations is essential, and the implementation of various conservation methods should be pursued collectively.

DECLARATION

The authors declare no conflict of interest.

REFERENCES

FAO. (1999). Women: Users, preservers and managers of agrobiodiversity. http://www.fao.org/3/x0171e/x0171e03.html

Ghimire, K.H., Manandhar, H.K., Pandey, M.P., Joshi, B.K., Ghimire, S.K., Karkee, A., Gurung, S.B., Ghimire, N.H., & Gauchan, D. (2022). Multi-environment screening of diverse finger millet landraces for blast resistance in Nepal. Journal of Nepal Agricultural Research Council, 8, 35-52. DOI: https://doi.org/10.3126/jnarc.v8i.44874

Gotame, T.P., Shrestha, S.L., Joshi, B.K., & Karki, T.B. (2019). Classification of crop plants based on growing season, Temperature Requirement and Photosynthetic Behavior. In B.K. Joshi & R. Shrestha (Eds), Working Groups of Agricultural Plant Genetic Resources (APGRs) in Nepal Proceedings of National Workshop (pp.103-120), 21-22 June 2018, Kathmandu; Nepal.

Joshi, B.K. & Shrestha, B.B. (2017). Notes on plant and crop classification. In B.K. Joshi, H.B. KC & A.K. Acharya (Eds), Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal Proceedings of 2nd National Workshop (pp. 17-20), 22-23 May 2017, Dhulikhel, Nepal.

Joshi, B.K., Bhattarai, M. & Shrestha, S. (2023). Catalog of germplasm accessions in Seed Bank, National Genebank (Nepal): Passport database Vol. I (NGRC-1 to 5000). National Agriculture Genetic Resources Center, NARC, Khumaltar, Lalitpur.

Joshi, B.K., Gorkhali, N.G., Pradhan, N., Ghimire, K.H., Gotame, T.P., KC, P., Mainali, R.P., Karkee, A. & Paneru. R.B. (2020). Agrobiodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council, 6, 14-33. DOI: https://doi.org/10.3126/jnarc.v6i0.28111

Joshi, B.K. (2022). 101 good practices and activities for conservation and utilization of agricultural genetic resources (AGRs). National Agriculture Genetic Resources Center, NARC, Khumaltar, Kathmandu. https://www.researchgate.net/publication/367279881

Karkee, A., Mainali, R.P., Basnet, S., Ghimire, K.H., Joshi, B.K., Thapa, P., Shrestha, D.S., Joshi, P. & Pokhrel, P. (2021). Agro-morphological characterization and intra-varietal diversity of Akabare chilli (*Capsicum* spp.) landraces of Nepal. SAARC Journal of Agriculture, 19(2), 37-55.

NAGRC. (2022). Annual report FY 2078/79. NAGARC (National Gnebank), NARC, Khumaltar, Lalitpur.

NAGRC. (2023). Annual report FY 2079/80. NAGARC (National Gnebank), NARC, Khumaltar, Lalitpur.

Thapa, P., Mainali, R.P., Karkee, A., Ghimire, K.H., & Joshi, B.K. (2022). Agro-morphological characterization and diversity assessment of rice accessions in Nepal. Agriculture Development Journal, 16, 72-82.