Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal

Alliance

Bioversity International

CIAT International Center for Tropical Agriculture

Tools and Research Results of the UNEP GEF Local Crop Project, Nepal

Editors: Devendra Gauchan, Bal Krishna Joshi, Bharat Bhandari, Hira Kaji Manandhar and Devra I. Jarvis

Kathmandu, Nepal, 2020





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Alliance

Kathmandu, Nepal
2020

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Published by: The Alliance of Bioversity International and CIAT, NAGRC and LI-BIRD
Published date: May 2020
Disclaimer: Views and contents expressed in the papers are those of authors

ISBN: 978-92-9255-181-0
NPSN: 00748-762/2019/20

Citation

Gauchan D, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds. 2020. Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal. Tools and Research Results of the UNEP GEF Local Crop Project, Nepal. NAGRC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal.

Copies: 500
Total contributors: 35
Total pages: 186 (excluding cover pages)
Total articles: 20

Available: I. NAGRC, Khumaltar, www.narc.gov.np; II. LI-BIRD, Pokhara, http://www.libird.org and III. the Alliance of Bioversity International and CIAT, Rome, www.bioversityinternational.org and www.himalayancrops.org

***Cover photo**: Clockwise from top right, i. Mountain landscape, Jungu, Dolakha; ii. Women homestay group, Lamjung receiving prize in National Food Fair; iii. Seed production, Jumla; iv. Crop biodiversity, seed production, Humla, and v. Community Seed Bank and prosomillet thresher inauguration, Humla. (Photo credit: D Gauchan, N Pudasaini, S Pant)*

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Tools and Research Results

Acknowledgements

This publication of project research results was made possible through the financial support of Global Environment Facility (GEF) and United Nations (UN) Environment, with co-funding from the Government of Nepal, Local Initiatives for Biodiversity Research and Development (LI-BIRD) and Bioversity International. Traditional crops cultivated in the Himalayan mountains are globally important components of agrobiodiversity that support dietary diversity, sustaining productivity and livelihoods of populations in Nepal. The smallholder farmers in the high mountain region of Nepal cultivate and consume diverse species and varieties of traditional crops over generation for their local food and nutrition security as well as income generation. These include nutrient dense and climate resilient crops such as buckwheat, barley, naked barley, different species of millets (finger millet, proso millet, and foxtail millet), amaranth and bean that have unique traits of stress tolerance adapted to harsh risk prone marginal mountain environments. However, these crops are generally under-valued, neglected and underutilized from the national agricultural research, education and development systems despite their critical role in adaptation to climate change and nutrition sensitive agriculture.

This book aims to document the importance of traditional mountain crops, the research and development actions, methodological tools, and approaches used to increase their value and utilization, as well as mainstreaming their use at the local decision making and national policy levels. The research team members from NARC, LI-BIRD and Bioversity International have jointly generated research results and piloted methodological tools, which are documented here in the form of research paper chapters. Research was carried out in four project sites of Humla, Jumla, Lamjung and Dolakha through the project "Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas", commonly called as Local Crop Project (LCP) from 2014 to 2019. The information generated was analysed, field validated, peer reviewed and edited by the editors for their finalization and inclusion in this book. Many of these papers were conceptualized and drafted in Writeshops conducted in 2015, 2016 and 2019 by the project that were held in Pokhara. They were further refined based on peer reviews of their presentation in project annual planning and review workshops, and in a national sharing workshop held in February 24, 2020. Twenty papers were selected from a peer review panel.

Most of these papers are the outcome of the work carried out in the project sites in partnership with Nepalese communities and relevant stakeholders at the local and national level. The papers cover results from field experiments of crop varietal mixture, disease management, climate trend and germplasm suitability analysis to seed system, incentives, gender studies, partnership building with the local community and government, including value chain development and mainstreaming of traditional mountain crops for food and nutrition security.

We take this opportunity to acknowledge all the farmers and community leaders of the four projects sites who directly involved on generating, testing and validating the results. We are particularly grateful for the work offered by all authors and contributors, and the support of project team members, including Rajeev Dhakal, Dipendra Ayer, Pitambar Shrestha, Dr Ram Bahadur Rana, Narayan Dhami, Aruna Parajuli, Achyut R. Adhikari, Subash Gautam, Saroj Pant, Pragati B. Paneru, Brinda K. Linkha, Sundar Raut, Purna Paudel, Epsha Palikhe, Anish Subedi, Ritesh K. Yadav, Rita Gurung, Niranjan Pudasaini and Shree R. Subedi. Our special thanks go to the project steering committee members, site management team members and national project coordinator Dr. Krishna Kumar Mishra including past national project coordinators (Drs Madan R. Bhatta, Mina N. Paudel, Bal K. Joshi) for technical support and guidance. We would like to specially thank to our project support team, Surendra Shrestha, Safal Khatiwada, Lila Jirel, Richa Gurung, Hem GC, Laxmi Gurung, Mira Dhakal and Kheem Pun. We also express our appreciation to our institutional heads and the senior management teams, scientists and other professionals of the project partners (NARC, LI-BIRD, DoA, Bioversity International), for their wholehearted support and creating the enabling environment for the successful implementation of the project. Special thanks go to the late Dr. Bhuwon Sthapit, Bioversity International, Nepal office for his great insights, guidance and initial support in generating information and documenting papers to bring in this form.

The Editors

Foreword

Achieving long-term food and nutrition security will always remain a challenge in remote mountainous environments where presence of formal sector research and development agencies and private sectors are limited. In this context, exploiting biodiversity of traditional mountain crops can play important role to ensuring food and nutrition security by sustaining productivity and livelihoods of marginalized populations in Nepal Himalayas. Increased pressure to grow more foods for human population, market preferences, national polices and climate change are some of the triggering factors that shape agrobiodiversity worldwide. Nepal being agrobiodiversity rich mountainous country, many globally significant crops genetic resources are being maintained by farmers in their production systems. National and international experts have been involved for the conservation, promotion and sustainable utilization of agricultural genetic resources since 1990s. Many community-based agrobiodiversity management processes, approaches and methods that were piloted in Nepal such as community seed banks, diversity fair, and four cell analysis are now widely used in many parts of the world. Exemplary action research has contributed significantly for long term availability of agricultural genetic resources. The role of farmers, researchers, policy makers and consumers are important in conserving and promoting native genetic resources through ex-situ, on-farm, in-situ and breeding strategies. Participatory tools developed, tested and validated in a particular site can be of great use to replicate in other areas for effective conservation and utilization of available genetic diversity. To accelerate the agrobiodiversity related work, three organizations namely, NARC, LI-BIRD and Bioversity International in partnership with the Department of Agriculture (DoA) have jointly implemented the project entitled “Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas” with the financial support from the Global Environment Facility through UN Environment since 2014. We are very pleased with the efforts put by the project team in bringing this excellent publication as an outcome of the project for documentation and wider dissemination. We thank the editors, authors, project team members, contributors, including farmers and other stakeholders for their hard work and strong team spirit they demonstrated in developing and bringing out this publication on time. The efforts of the editors, reviewer and authors are noteworthy as they have been able to document and finalize their research products as an outcome of the project. We believe that this document will be read widely and will serve as a valuable reference for researchers, development professionals, students, academicians and relevant stakeholders to accelerate the conservation and utilization of traditional mountain crop biodiversity for food and nutrition security in Nepal and globally.

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Uncommon Abbreviations

ABS	Access and Benefit Sharing
ACSBN	Association of Community Seed Banks in Nepal
APGR	Agricultural Plant Genetic Resource
CBM	Community Biodiversity Management
DG	Director General
CDABCC	Crop Development and Agricultural Biodiversity Conservation Centre
CSB	Community Seed Bank
DF	Diversity Fair
DFF	Diversity Field Flora
DFTQC	Department of Food Technology and Quality Control
DoA	Department of Agriculture
ED	Executive Director
FCA	Four Cell Analysis
FFS	Farmers' Field School
FFT	Farmers' Field Trial
FGD	Focus Group Discussion
FRD	Food Research Division
GEF	Global Environment Facility
GI	Geographic Indication
HDI	Household Diversity Index
IRD	Informal Research and Development
KII	Key Informant Interview
LCP	Local Crop Project
LI-BIRD	Local Initiatives for Biodiversity, Research and Development
MoICS	Ministry of Industry, Commerce and Supplies
NAGRC	National Agriculture Genetic Resources Centre (Genebank, National Genebank)
NARC	Nepal Agricultural Research Council
NPC	National Project Coordinator
NSB	National Seed Board
PMU	Project Management Unit
PPB	Participatory Plant Breeding
PRA	Participatory Rural Appraisal
PSE	Participatory Seed Exchange
PVS	Participatory Variety Selection
SEAN	Seed Entrepreneurs' Association of Nepal
SMT	Site Management Team
SQCC	Seed Quality Control Centre
UNEP	United Nations Enviornment Program
VDC	Village Development Committee

Project Introduction

UNEP GEF LOCAL CROP PROJECT

Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas

Nepal is a part of the Hindu-Kush Himalayan system, with its outlying subranges, which stretches across seven countries (Afghanistan, Pakistan, India, China, Nepal, Bhutan, Mynamar), with the longest division over 1500 km in Nepal. The region, with extreme variations in topography and micro-environments, harbours centres of unique traditional crop diversity adapted to mountain environments. The diversity of local traditional varieties, with globally important cold-tolerant genes, is one of the few natural resources available to mountain farmers to cope with marginal and heterogeneous environments that are likely to be starkly affected by climate change. These traditional crops are also important for sustainable development of their local economy. The key to the sustainability of the high mountain agroecosystems in Nepal is that farmers have continued to keep a large diversity of traits in their traditional varieties, despite the bottleneck of cold stress and harsh mountainous environments. In these vulnerable environments, diversity in the production system can support ecosystem provisioning, cultural and regulating services and buffer the risks of pest, disease and environmental stresses. Yet, little research and development has been done focussing on these important, nutritious and climate-resilient crops from the perspective of breeding, processing, promotion and policies. The project aims to mainstream the use of diversity-rich solutions in the mountain agroecosystems to improve ecosystem services provisioning and resilience and promote access and benefit sharing among local communities. It aimed to develop and promote diverse sets of varieties, improve access to diverse sets of planting materials and drudgery-reducing processing technologies and promote an enabling environment for access to and benefit-sharing.

Project Goal

To contribute to the conservation of globally important crop biodiversity, which form the basis for food security in areas of high environmental instability and variability in many high elevation agricultural systems throughout the world.

Project Objective

To mainstream the conservation and use of agricultural biodiversity in the mountain agricultural production landscapes of Nepal to improve ecosystem resilience, ecosystem services and access and benefit-sharing capacity in the mountain communities.

Crops and Sites

The project worked on eight neglected and underutilized mountain crops, namely, buckwheat (*Fagopyrum esculentum* and *F. tararicum*), cold tolerant high altitude rice (*Oryza sativa*), common bean (*Phaseolus vulgaris*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), grain amaranth (*Amaranthus caudatus* and *A. hypochondriacus*), naked barley (*Hordeum vulgare* var. nudum), and proso millet (*Panicum miliaceum*). The research work was conducted in high elevation mountain agroecosystesm (>1500 - 3000msl) of Humla, Jumla, Lamjung and Dolakha districts representing western, central and eastern part of the Nepal mountains.

National Partners and Project Execution

The project is being executed by Bioversity International through UN Environment with the funding support of the Global Environment Facility (GEF). The executing national partners are Nepal Agricultural Research Council (NARC), the Department of Agriculture (DoA), and Local Initiatives for Biodiversity, Research and Development (LI-BIRD) in Nepal.

Donors

The GEF Trust Fund provided USD 2.3 million in grant, which was made available through UN Environment. The four implementing and executing partners (UN Environment, Bioversity International, the Government of Nepal mainly NARC and LI-BIRD) provided additional USD 5.8 million in cash and in-kind cofinancing. This made a total of USD 8.1 million. The project was supported by the CGIAR Research Program on Water, Land and Ecosystems (WLE), a program to provide an integrated approach to natural resource management research.

Project Management

The project was implemented from April 2014 to March 2020 by the UN Environment and executed by Bioversity International in partnership with NARC, DoA and LI-BIRD. The National Agriculture Genetic Resources Centre also known as the National Genebank, NARC hosted the Project Management Unit (PMU) and the Chief, acted as the National Project Coordinator (NPC). The PMU was consisted of the NPC, supported by a National Project Manager and a National Project Assistant. The PMU was supported at the site level by project leaders from executing agencies and the Site Management Teams supported by the District Coordination Committees. The project team was assisted by an interdisciplinary core team and thematic experts known as the National Technical Coordination Committee. At the national level, the project was governed by National Project Steering Committee (PSC), chaired by the Joint Secretary of the Ministry of Agricultural and Livestock Development (MoALD) involving representation of key stakeholders such as Minstry of Forestry and Environemnt (MoFE), Ministry of Finance (MoF), NARC, LI-BIRD, ICIMOD, UNEP and Bioversity International including a woman farmers' representative from the project sites. The role of the Project Steering Committee was to review the overall progress of the project and provide policy decisions about the implementation of the project and play a proactive role in mainstreaming good practices into national policies.

Working Approach

The project cultivated partnerships with public, private and civil society organizations (CSOs) and leveraged resources for implementation of project activities and mainstreaming lessons and good practices. Community biodiversity management (CBM) approaches were employed to manage and use traditional crop diversity and empower local institutions to effectively participate in local governance processes to set up and implement relevant research fordevelopment agenda. Many activities were implemented under the three envisoned project components, which are

- Component 1: Mainstreaming mechanisms that integrate diversity-rich solutions into breeding and technology
- Component 2: Increasing access to local agrobiodiversity planting materials
- Component 3: Promoting an enabling environment for access and benefit sharing of local agrobiodiversity planting materials

Local, National and Global Benefits

Local communities have improved capacity of managing diverse sets of agricultural biodiversity for improved production and risk management and have better access to planting materials and processing equipment. Nationally and globally important cold, drought and pest tolerant germplasm of eight target crops have been conserved and made accessible to farmers and other stakeholders in Nepal.Tools, methods and approaches for conservation and sustainable use of agrobiodiversity are developed and piloted during the project period for upscaling and mainstreaming at the local, national and international level. Capacity of local farming communities, research and development professionals and private sectos are built in the conservation, promotion and mainstreaming of traditional mountain crop biodiversity. The expertise and experience gained from the project implementation period has been influencing in the development of supporting programs and policies for the promotion of traditional crop diversity and nutrition sensitive agriculture. Project has developed and published several knowledge products such as books, booklets, journal papers, research reports, briefs, information flyers, project videos etc in both English and local langauge and maintained them in the project website (www.himalayancrops.org) that are being widely shared and freely available to the global community.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Cultivar Mixture for Minimizing Risk in Farming and Conserving Agrobiodiversity

Bal Krishna Joshi, Shree Prasad Vista, Suk Bahadur Gurung, Krishna Hari Ghimire, Rita Gurung, Saroj Pant, Subash Gautam and Pragati Babu Paneru

ABSTRACT

Conservation along with sustainable production of crops using crop diversity has been a priority work of relevant stakeholders in mountain agriculture. With respecting and improving tradition of mixing native landraces, replicated trials were conducted on different mixtures of improved varieties and landraces and sole cultivars of rice, buckwheat, bean, naked barley and finger millet in Humla, Jumla and Dolakha districts in Nepal. Both on-farm and on-station trials were conducted as a randomized complete block design following farmers' cultivation practices in 2016, 2017 and 2018. In majority of traits in all crops, the performance of mixture plots was found significantly better than the treatments planted in sole. Low infection of diseases and higher seed setting in mixture plots of common buckwheat indicated the scope of mixture in different crops and diverse ecological setting. Mixing landraces can help conserve crop diversity without compromising grain yield. Potential to increase yield would be higher in mixture if proper types and proportion of better mixing ability landraces is identified. Favorable research, education and development policies should be developed for mixture varieties to further enhance such local technique. In long term, mixture of varieties leads to create an evolutionary population which are more climate resilient and, contribute to stabilize and sustainably increase crop yield. This technique can be easily adopted by smallholder farmers and it is one of the good strategies for conservation and low risk crop production.

Keywords: Conservation, cultivars, disease, diversity, landraces, mixture, varieties

INTRODUCTION

Modern agriculture system is associated with unsustainability, prone to genetic erosion and higher dependency on external inputs. Cultivar mixture is an old age practice and a simple and sustainable genetic resources management system that helps increase yield, provide yield stability, conserve genes, manage biotic and abiotic stresses (buffer against disease infection) and restrict the spread of disease considerably. It is the mixtures of cultivated varieties growing simultaneously on the same parcel of land with no attempt to breed for phenotypic uniformity (Mundt 2002). Some traits are enhanced and some suppress in the mixture. Functional diversity (differences in disease resistance and other agronomic traits of cultivars) leads to higher stability (Petchey and Gaston 2002). The usefulness of mixtures for disease management was well demonstrated for rusts and barley powdery mildews of cereals (Finckh et al 2000, Mundt 2002, Pradhanang and Sthapit 1995, Sharma and Dubin 1996). Multiline cultivars of rice are used to prevent the breakdown of blast resistance in Japan, where the first registered rice multiline was released in 1995 (Koizumi 2001). The large-scale experiment in Yunnan, China demonstrated that blast was controlled and yield had been increased through traditional cultivars and inter-planted hybrid rice (Zhu et al 2000). Mixtures of wild and domesticated crops have also been studied (Joshi et al 2017) to see competition between them. It is one of the good practices for managing agrobiodiversity (Joshi et al 2020a).

Farmers commonly face crop failure due to abiotic and biotic factors. Thus, farmers grow several cultivars in a field or adjacent field as a strategy to cope with risks associated with heterogeneous and uncertain ecological and socioeconomic conditions. Mixture may be at genus, species, cultivar and gene levels. Intraspecific mixture may be defined as multivar or varietal blend. Interspecific mixture is very common practices in sustainable agriculture. However, varietal blend is being practiced in some crops at certain locations. Objectives of the current studies were to develop multivar (mixture of cultivars); to manage biotic and abiotic factors; to understand the mechanism of intra and inter varietal diversity for reducing vulnerability and for higher seed setting; to evaluate farmer's mixture component and identify best component.

MATERIALS AND METHODS

Protocols were developed on landraces and varieties selection, experimental site selection and design, agronomical practices and data recording, and discussed among the team members. On-station trials were conducted in the Agriculture Research Station (ARS), Bijayanagar for rice, bushy bean and pole bean, and the Hill Crop Research Program (HCRP), Kabre for finger millet, common buckwheat and naked barley. On-farm trials were conducted in Chhipra, Humla and Hanku, Jumla for bean. Cultivars (landraces and varieties) were selected based on the criteria developed with respect to objectives (**Table** 1). Released and registered genotypes are termed here as varieties and farmer's varieties as landraces. Cultivars (that covers both landraces and varieties) available around the experimental sites and climate analog of these sites were used. List of landraces and varieties along with sources and experimental years are given in **Table** 2. A key informant survey was conducted on each site for understanding standard farmers' practices. Based on the objectives, sole and mixture treatments were developed with different combinations from identified cultivars. There were single (also called sole, mono) variety, biblend mixture, triblend mixture, tetrablend and pentablend mixture and farmer's variety (local landrace). Experimental details are given in **Figure** 1. Data were recorded following standard system. In this paper, only targeted traits were analyzed and reported. Details of each experiment for each of crops are described in other papers.

Table 1. Criteria and traits for selecting cultivars to mix together based on objectives of cultivar mixture

For space use	For disease and insect pests management	For drought management	Trait to be similar among components
Different root length	Different reaction capacity with insect pests and diseases	Deep root	Maturity
Different plant height	Different leaf and stem texture	Erect plant/leaf	Cooking method
Different plant structure	Different color and size	Different plant height	Milling
Different size	Different scent	Large leaf but few in number	Genetics
Different plant shape	Different inflorescence	Shiny and rough leaf	Cooking time

Table 2. List of cultivars (landrace and varieties) used in mixture trials in three districts (Humla, Jumla and Dolakha)

Crop (site)	Landraces	Source	Varieties	Source	Year tested
Bean (Simikot, Humla)	Kaalo Saano, Raato Maale, Kaalo Maale, Khairo Simee, Local mixture	Humla	PB0001, PB0048, KBL1	ARS, Bijayanagar	2017, 2018
Bean (Hanku, Jumla)	Kaalo Maale, Kaalo Saano, Raato Saano, Local mixture	Jumla	PB001, KBL-01, PB0048	ARS, Bijayanagar	2017, 2018
Bean, Pole type (Bijayanagar, Jumla)	X	X	PB-0002, KBL-1, KBL-2, KBL-3	ARS, Bijayanagar	2016, 2017, 2018
Bean, Bushy type (Bijayanagar, Jumla)	X	X	PB-0001, KBL-5, KBL-8	ARS, Bijayanagar	2016, 2017, 2018
Rice (Bijayanagar, Jumla)	NGRC-03159 (Jumli Dhaan), NGRC-03160 (Jumli Maarsee), NGRC-03161 (Kaalo Maarsee), NGRC-03162 (Raato Maarsee), Jumli Maarsee, Daarime, Jumli Maarsee Mehele	NAGRC, Khumaltar and Jumla	Chandannaath-1	ARS, Bijayanagar	2016, 2017, 2018
Finger millet (Kabre, Dolakha)	ACC#2695, ACC#2605, ACC#425, ACC#2343	HCRP, Kabre	X	X	2017, 2018
Naked barley (Kabre, Dolakha)	NGRC02306, NGRC04003, NGRC04894, NGRC04902	NAGRC, Khumaltar	X	X	2017
Common buckwheat (Kabre, Dolakha)	ACC#5670, ACC#2213, ACC#6529, ACC#2234	HCRP, Kabre	IR13	HCRP, Kabre	2016, 2017, 2018

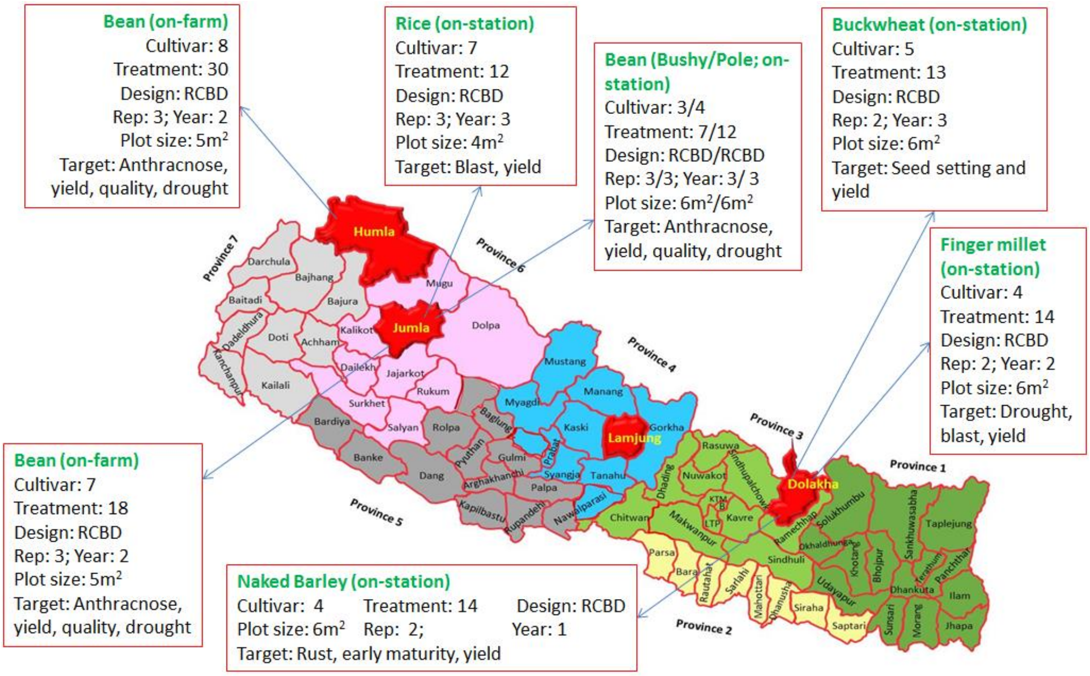

Figure 1. Experimental sites and details of cultivar mixtures in three districts (Humla, Jumla and Dolakha).

Data were entered in Excel for recording validation and exploratory data analysis. Conventional RCBD analysis was done using Minitab. Least Significant Difference (LSD) values are reported for mean separation at 5% level of significance. Regression analysis was applied to see the effects of number of cultivars in bean mixture on yield.

RESULTS AND DISCUSSION

Two types of genotypes ie varieties (released or registered variety) and landraces were considered in mixture trials targeting to identify better combination for grain yield and stress management. Multivar (mixture of more than two cultivars) was better for managing abiotic and biotic factors (unpredictability factors) rather than considering only yield. Farmers are following mixing of different genotypes in bean from an ancient time (Joshi et al 2020b). This might be the reason that their components have the higher mixing ability resulted in higher and stable grain yield. Mixture practice is not common as bean in other crops. A local crop project, a project jointly implemented by Nepal Agricultural Research Council (NARC), Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and Bioversity International, conducted experiments on mixing different genotypes in bean and other crops in four project sites. Results of mixture experiments are given below for each crop (rice, bean, buckwheat, finger millet, naked barely).

Rice cultivar mixture

The performance of sole and mixture of rice landraces and varieties are given in **Table** 3a and 3b with regards to yield and disease infection. In 2016, there was no clear difference between mixture and sole cultivation of rice cultivars, however, significant difference was found among the treatments for yield, leaf blast and neck blast. Jumli Maarsee and Raato Maarsee were found better to consider as components in the mixture. In 2017, significance differences were only for lodging and neck blast among the treatments and grain yield was highly significant in 2018 (**Table** 3b). The panicle number was the highest in mixture of all three landraces and one modern (released) variety. Mixture of Jumli Maarsee and Chandanaath-1 produced the highest grain yield. Chandanaath-1 was found good for yield, lodging resistance and blast management in mixtures. There is potential of getting extra benefit on grain yield and stresses management from mixture, however, selection of better components are the preliminary and most important factors to take account in mixture. Over the long time, mixtures become more competitive and develop higher mixing ability resulted in higher grain yield and tolerant to abiotic and biotic stresses, and therefore needs more experiments over the time.

Table 3a. Performance of rice genotypes in mixture trial at ARS, Vijaynagar, Jumla during 2016

EN	Landrace	Grain yield, kg/ha	Leaf blast	Neck blast
1	NGRC-03159 (Jumli Dhaan)	4022	5.0	5.7
2	NGRC-03160 (Jumli Maarsee)	8195	3.0	2.7
3	NGRC-03161 (Kaalo Maarsee)	3858	5.0	7.0
4	NGRC-03162 (Raato Maarsee	7717	4.7	2.3
5	1+2	4033	3.0	5.0
6	1+3	6117	4.0	3.3
7	1+4	5692	3.7	3.7
8	2+3	6917	3.3	2.7
9	2+4	6589	3.7	3.7
10	3+4	7489	4.0	3.7
11	2+3+4	4803	3.7	4.0
12	1+2+3+4	6347	3.0	2.7
	F test	**	*	**
	LSD, 0.05	1189.00	1.45	2.17

Blast score was at 0-9 scale. Number with plus sign indicates the combination of landraces as per the entry number. EN, entry number.

Table 3b. Performance of rice genotypes in mixture and sole trials at ARS, Jumla during 2017 and 2018

EN	Genotype	2017						2018
		PN/hill	GY, kg/ha	LDG	BLB	BL	NB	GY, kg/ha
1	Jumli Maarsee Daarime	17	4891.67	9.00	3.67	4.67	5.67	3323.33
2	Jumli Maarsee Mehele	12	4144.45	9.00	3.00	3.00	3.00	
3	Kaali Maarsee	18	4372.22	9.00	4.00	4.67	4.67	4134.17
4	Chandannaath-1	14	5697.22	3.00	2.33	3.33	0.00	7295.83
5	1+2	16	5309.72	9.00	4.00	4.33	5.00	3363.33
6	1+3	16	3680.55	7.00	4.33	4.00	4.33	2602.50
7	1+4	18	4433.33	7.00	3.67	4.00	4.33	4180.00
8	2+3	17	5088.89	9.00	3.00	4.33	3.67	3476.67
9	2+4	9	6322.22	5.00	2.33	3.67	2.67	
10	3+4	19	5891.67	5.00	2.67	3.33	3.67	4077.50
11	2+3+4	16	5930.56	7.67	2.67	2.33	2.67	
12	1+2+4							3763.33
13	1+2+3+4	20	4533.34	7.67	3.33	4.00	4.33	3744.17
	P-value	0.61	0.32	0.01	0.10	0.28	0.02	<0.001
	LSD, 0.05			5.9			4.68	5.07

PN, panicle number; GY, grain yield; LDG, lodging; BLB, bacterial leaf blight; BL, blast, NB, neck blast. Lodging and disease scores were at 0-9 scale. Number with plus sign indicates the combination of landraces as per the entry number. EN, entry number.

Bean cultivar mixture

Bean mixture in Humla and Jumla is a very common old age practice. Farmers, consumers, and traders all prefer bean mixture because of high yield, low diseases and insect pests infestation, good production even from drought and poor land, high market price, good taste, low problem during storage and help to minimize risk on bean production (Palikhey et al 2017, Joshi et al 2020b). Common seeds in mixture are red, black, white and mosaic. Farmers said mixture practices are not adopted in other crops because of different maturity times and taste; mixture also deteriorates taste. Mostly 3-4 types of seeds are better in mixture, and there is high demand of mixture with black seed.

On-farm bean mixture, Humla

Significant difference was found only in 2017 on root length and grain yield among sole and mixture treatments (Table 4). Root length of PB0048 was longest in both years 2017 and 2018. The shortest root length was noticed in the mixture of Kaalo Saano+Kaalo Maale+PB0001. Anthracnose infection was lower in mixture in 2017, but not in 2018. Grain yield was also higher in mixture plots in both years 2017 and 2018. The number of bean cultivars mixed during the cultivation has significantly contributed to yield (the regression coefficient (b=125 kg/ha) of number of cultivars (p=0.001). The best mixture was Kaalo Saano+Raato Maale+Khairo Simee in 2017 and Raato Maale+Kaalo Maale+PB0001 in 2018.

Table 4. Performance of bean mixture and sole genotypes tested on-farm in Simikot, Humla during 2017 and 2018

SN	Mixture and sole genotype	2017			2018		
		Root length, cm	Anthracnose	Grain yield, kg/ha	Root length, cm	Anthrac-nose	Grain yield, kg/ha
1.	E	15.40	4.33	662.0	18.27	4.33	1331
2.	F	17.33	3.00	806.0	13.67	2.33	948
3.	G	21.00	3.00	601.3	17.07	3.00	1332
4.	H	14.27	3.66	954.0	13.93	3.00	1373
5.	AB	13.07	3.00	1445.0	-	-	-
6.	ABC	13.47	4.33	1104.0	-	-	-
7.	ABCD	13.47	3.00	1770.0	14.33	3.00	1256
8.	ABCDE	16.00	2.33	785.7	13.33	3.00	1243
9.	ABCE	13.20	3.00	1227.0	16.20	3.00	1120
10.	ABD	14.00	3.00	1794.7	-	-	-
11.	ABE	16.73	2.33	1636.0	15.13	3.67	1101
12.	AC	15.13	3.00	806.0	-	-	-
13.	AD	12.07	3.66	601.3	-	-	-
14.	ADC	15.60	3.00	1776.0	-	-	-
15.	AE	14.87	3.66	735.0	-	-	-
16.	BC	13.33	1.66	1227.0	-	-	-
17.	BCD	16.00	3.00	1488.0	-	-	-
18.	BCDE	15.00	3.00	1563.0	12.20	2.33	1181
19.	BCE	16.60	3.00	1703.0	14.13	3.00	1598
20.	BD	15.93	3.00	1563.0	-	-	-
21.	BE	13.47	3.00	1549.0	16.13	3.00	1067
22.	CD	17.07	3.66	914.0			
23.	CDE	19.67	3.00	1776.7	13.20	3.67	1117
24.	CE	13.40	3.00	785.7	-	-	-
25.	CEDA	15.13	3.00	1549.0	-	-	-
26.	DCE	13.00	3.00	1556.0	-	-	-
27.	DE	15.73	4.33	662.0	-	-	-
28.	DEA	16.07	3.00	1614.0	-	-	-
29.	DEB	16.80	3.66	1729.3	16.47	3.67	1397
30.	EABD	17.40	3.00	914.0	16.20	3.67	1349
31.	EAC	12.87	3.00	1414.0	12.87	3.00	1507
	P value	0.05	0.39	<0.0001	0.31	0.73	0.94
	LSD, 0.05	4.5	-	454.44	-	-	-

A=Kaalo Saano, B=Raato Maale, C=Kaalo Maale, D=Khairo Simee, E=PB0001, F=KBL1, G=PB0048, H=Farmer variety. Two and more than 2 alphabets are the combination of genotypes as indicated before.

On-farm bean mixture, Jumla

Results of on-farm trials in Jumla are given in Table 5. Root length in 2017 and anthracnose infection in 2018 was significantly different among treatments (sole and mixture plots). Root length of Raato Saano was longest and of Kaalo Saano shortest. Variation in root length is important for drought management and nutrient uptake from all areas. PB0048 was infected heavily by anthracnose in 2018 in comparison with other treatments. In 2017, mixture plots produced higher grain yield and Kaalo Maale+PB001 produced highest grain yield in 2018. Local mix is the mixture of different landraces which produced the higher grain yield in both years. This mixture might have better companion component along with higher mixing ability developed over the continued cultivation and selection.

Table 5. Performance of bean mixture and sole genotypes tested on-farm in Hanku, Jumla during 2017 and 2018

SN	Mixture and sole genotype	2017		2018	
		Root length, cm	Grain yield, kg/ha	Anthracnose	Grain yield, kg/ha
1.	A	17.85	1740.6	0.33	2148.0
2.	B	17.26	1718.0	0.33	1566.0
3.	C	25.69	1720.6	0.00	1695.4
4.	D	20.36	1784.6	0.00	1927.4
5.	E	21.60	1632.0	0.67	1577.4

SN	Mixture and sole genotype	2017		2018	
		Root length, cm	Grain yield, kg/ha	Anthracnose	Grain yield, kg/ha
6.	F	21.47	1620.0	1.00	1556.0
7.	G	21.94	1924.6	0.00	2222.0
8.	AB	21.30	1657.4	0.00	1433.4
9.	ABC	24.58	1518.0	0.00	1648.0
10.	ABCD	20.63	1470.0	0.00	1718.0
11.	ABD	20.27	1661.4	0.00	1821.4
12.	AC	25.61	1564.0	0.00	1834.6
13.	ACD	23.11	1362.6	0.00	1924.0
14.	AD	20.10	1809.4	0.00	2018.6
15.	BC	23.04	1780.0	1.00	1628.6
16.	BCD	23.55	1710.0	0.33	1848.0
17.	BD	21.71	1571.4	0.66	1844.0
18.	CD	22.26	1882.0	0.00	1826.0
	p value	<0.0001	0.237	0.007	0.724
	LSD, 0.05	1.68	357.6	0.63	

A=Kaalo Maale, B=Kaalo Saano, C=Raato Saano, D=PB001, E=KBL-01, F=PB0048, G=Local mix. Two and more than 2 alphabets are the combination of genotypes as indicated before.

Bush bean on-station

Grain yield was not significantly different among sole and mixture treatments in all three years. PB-0001+KBL-5 produced the higher yield in both 2016 and 2017 but in 2018, KBL-5 yielded the highest (Table 6). The lower scores were observed in mixture plots for anthracnose and powdery mildew infection. PB-0001+KBL-5+KBL-8 mixture was superior in all years for higher number of traits eg number of pods, grain yield and powdery mildew.

Table 6. Performance of bushy bean mixture and sole genotypes tested on-station in Bijayanagar, Jumla

SN	Mixture and sole genotype	2016				2017				2018			
		PD/PL, n	GY,kg/ha	ANTH	PM	PD/PT, n	GY, kg/ha	ANTH	PM	PD/PL, n	GY, kg/ha	ANTH	PM
1	PB-0001	6	634	5.0	3.3	8	785.6	5	3	9	1288	3	6
2	KBL-5	6	634	7.0	5.7	11	749.4	7	4	7	1890	7	8
3	KBL-8	4	396	7.0	5.0	14	693.9	7	6	6	864	8	8
4	PB-0001+ KBL-5+KBL-8	8	688	5.0	4.3	7	1198.3	6	4	10	1361	4	5
5	PB-0001+KBL-5	7	754	5.0	3.3	5	882.2	6	4	10	1715	4	6
6	PB-0001+KBL-8	6	676	4.3	3.3	6	675.6	6	3	9	1073	5	6
7	KBL-5+KBL-8	4	369	5.0	3.7	12	573.3	6	5	7	1758	8	8
	F test	NS	NS	**	NS	**	NS	NS	**	NS	NS	*	*
	LSD, 0.05	-	-	1.55	-	3.60	-	-	1.3	3.97	1175	2.99	1.97

GY, grain yield; PM, powdery mildew (0-9); Anth, Anthracnose (0-9); PD/Pl, number of pods per plant.

Pole bean on-station

Pole bean experiment had included elite lines selected at ARS, Bijayanagar, Jumla. Three years results have shown that on an average, mixture performed better in terms of grain yield, pod number, disease suppression (anthracnose and powdery mildew) (Table 7). In 2016, KBL-1+KBL-3 had the higher number of pods per plant. KBL-2 produced the highest yield followed by KBL-1+KBL-2. Mixtures with KBL-3 and PB-0002 were less affected by anthracnose in 2016. The pod numbers of PB-0002+KBL-3 and KBL-1+KBL-2 were higher in 2017. The lowest score of anthracnose and powdery mildew were observed in mixture plots of PB-0002+KBL-2 and PB-0002+KBL-1, respectively in 2017. PB-0002+KBL-2 produced the highest yield in 2017 and KBL-2+KBL-3 in 2018. In general, mixtures of KBL-1+KBL-3 and KBL-2+KBL-3 were found better.

Buckwheat cultivar mixture

Three years experiments on mixture of buckwheat cultivars indicated that, mixture is better for higher number of seed setting, getting higher grain yield, and minimizing the infection of Botrytis leaf spot and powdery mildew diseases. The mixture plot of ACC#2213+ACC#2234+IR13 had the highest number of seed per cyme and grain yield in both 2016 and 2018 years. The highest grain yield was found in ACC#6529+ACC#2234+IR13. Released variety ie IR13, grown in a single plot had also high number of seed setting as well as the lowest infection of powdery mildew in 2017 and 2018, respectively.

Table 7. Performance of pole (trailing) bean mixture and sole genotypes tested on-station in Bijayanagar, Jumla

SN	Mixture and sole genotype	2016				2017				2018	
		PD/PL, n	GY, kg/ha	ANTH	PM	PD/PT, n	GY, kg/ha	ANTH	PM	PD/PL, n	GY, kg/ha
1.	PB-0002	14	2065	0	3.3	8	2051.1	4	3	12	2078.61
2.	KBL-1	15	2583	2	4.0	10	1882.2	4	3	11	1835.63
3.	KBL-2	14	3274	1	3.0	11	2566.7	4	4	12	2737.78
4.	KBL-3	12	2075	0	5.0	8	2358.3	4	3	15	2370.65
5.	PB-0002+KBL-1	14	2060	2	5.0	9	2181.1	4	2	15	2243.09
6.	PB-0002+KBL-2	15	2568	2	3.3	10	3312.2	3	3	15	2521.47
7.	PB-0002 KBL-3	15	2576	0	4.3	11	2423.9	4	3	13	2640.57
8.	KBL-1+KBL-2	13	3021	2	6.3	11	2538.9	4	3	14	2522.06
9.	KBL-1+KBL-3	16	2614	2	7.0	10	2625.6	4	3	15	2610.15
10.	KBL-2+KBL-3	17	2966	0	5.0	9	2128.9	4	3	15	2768.28
11.	KBL-1+KBL-2+KBL-3	14	2758	0	7.0	10	2615.0	4	3	12	2207.76
12.	PB-0002+KBL-1+KBL-2+KBL-3	16	2862	0	4.3	8	2447.8	4	3	13	2536.27
	F test	NS	**	-	**	NS	NS	NS	NS	NS	NS
	LSD, 0.05	-	631.7	-	1.82						

GY, grain yield; PM, powdery mildew (0-9); Anth, Anthracnose (0-9); PD/PL, pod number per plant.

Major problem in common buckwheat is poor seed setting, mainly because of self-incompatibility. It has two types of flowers ie pin and thrum flowers and both flowers are needed to set the seed. Mixture with the right proportion of these flowers is therefore a main and simple strategy to increase grain yield. Significant role (p=0.05 for regression coefficient) of a number of different landraces on seed setting of buckwheat had been observed. Seed setting can further greatly be enhanced if we can mix pin and thrum types of flowering landraces. In mixture plot, number and diversity of insect pollinators and their duration of visits were higher compare to sole cultivar plot. This might be the reason for the higher number of seed setting in mixture plot.

Table 8. Performance of buckwheat cultivars in sole and mixture plots over three years

Mixture and sole genotype	2016		2017				2018			
	Seed/ cyme, n	GY, kg/ha	Seed/ cyme, n	GY, kg/ha	AUDPC (BLS)	AUDPC (PM)	Seed/ cyme, n	GY, kg/ha	AUDPC (BLS)	AUDPC (PM)
ACC#5670	7	687.50	7	773	81	63	6	2200	56	33
ACC#2213	8	797.50	9	717	81	33	6	1640	49	19
ACC#6529	6	755.00	7	780	74	42	7	2020	60	35
ACC#2234	7	725.00	7	703	70	40	7	2180	67	49
IR13	9	805.00	9	926	70	70	5	2000	53	18
ACC#5670+ACC#2213	7	667.50	7	354	60	82	6	2180	63	25
ACC#6529+ACC#2234	8	850.00	8	769	81	40	5	2120	63	35
ACC#2213+ACC#2234	9	680.00	8	850	63	53	5	1190	60	33
ACC#2234+IR13	8	890.00	7	666	91	23	7	2280	46	26
ACC#2213+ACC#6529+ ACC#2234	7	725.00	8	302	53	61	6	1810	46	44
ACC#5670+ACC#2213+ ACC#6529	8	807.50	6	561	67	21	6	1990	42	49
ACC#6529+ ACC#2234+IR13	8	837.50	8	1249	53	70	7	2490	74	26
ACC#2213+ACC#2234+ IR13	9	912.50	7	961	67	35	8	2310	46	32
p-value	0.571	<.001	0.661	<0.001	0.446	0.006	0.002	0.002	0.95	0.65
LSD, 0.05	2.7	52.49	2.9	175	33.97	27.3	0.9	418	48.9	34.9

BLS, Botrytis Leaf Spot; PM, Powdery mildew; GY, grain yield; AUDPC, area under disease progress curve.

Finger millet cultivar mixture

The performance of finger millet landraces in sole and mixture system is given in **Table** 9. In both years (2017 and 2018), there was significant difference among different combination of landraces for finger blast infection and grain yield. The lowest incidences of finger blast and neck blast were observed in mixture plot of ACC#2605+ACC#2343, ACC#425+ACC#2343, and ACC#2605+ACC#425 in 2017. The neck blast incidence was the highest in a mixture of ACC#2695+ACC#425. Genotypes selection in mixture is therefore very important for getting better results, based on the objectives. Triblend plot (ACC#2605+ACC#425+ACC#2343) produced the highest grain yield in 2017, followed by another triblend (ACC#2695+ACC#2605+ACC#425). Mixtures of ACC#2605+ACC#425+ACC#2343 and ACC#425+ACC#2343 were found more tolerant to finger and neck blast in 2018. The mixture plot of ACC#2695+ACC#2605+ACC#425 produced the highest grain yield followed by ACC#2695+ACC#2605+ACC#425+ACC#2343 in 2018. The combinations of ACC#2695+ACC#2605+ACC#425 and of ACC#425+ACC#2343 were better mixture in reducing blast infection and getting higher grain yield.

Table 9. Performance of finger millet cultivars in sole and mixture plots in Kabre, Dolakha, 2017 and 2018

SN	Mixture	2017			2018		
		Finger blast, %	Neck blast, %	GY, kg/ha	Finger blast, %	Neck blast, %	GY, kg/ha
1.	ACC#2695	10	15	3270	8	30	3000
2.	ACC#2605	12	25	2060	19	30	2200
3.	ACC#425	23	25	3400	9	15	2500
4.	ACC#2343	27	20	2850	8	5	1800
5.	ACC#2695+ACC#2605	14	25	2000	8	25	2300
6.	ACC#2695+ACC#425	16	40	3480	7	10	2300
7.	ACC#2695+ACC#2343	9	25	3300	4	20	2400
8.	ACC#2605+ACC#425	15	0	2920	12	15	2200
9.	ACC#2605+ACC#2343	6	5	2860	2	5	2200
10.	ACC#425+ACC#2343	4	30	3170	15	0	2900
11.	ACC#2695+ACC#2605+ACC#425	14	25	3760	3	10	3300
12.	ACC#2695+ACC#2605+ACC#2343	13	15	3720	11	15	2800
13.	ACC#2605+ACC#425+ACC#2343	12	25	3940	0	10	3000
14.	ACC#2695+ACC#2605+ACC#425+ ACC#2343	11	25	3430	19	25	3100
	p-value	0.01	0.156	0.002	0.05	0.349	0.052
	LSD, 0.05	9.1	-	751	11.73	26.01	850

GY, grain yield.

Naked barley cultivar mixture

Significant differences were found among naked barley mixture treatments for tiller number, grain yield and AUDPC values of powdery mildew (Table 10). The highest tiller was found in NGRC 04003 followed by triblend mixture. This triblend mixture produced the highest grain yield and had the lowest AUDPC for powdery mildew. Sole landrace plots had generally higher AUDPC, indicating the mixture of naked barley reduced the infection of powdery mildew.

Table 10. Performance of naked barley genotypes in sole and mixture plots in Kabre, Dolakha in 2018

SN	Mixture	Tiller/m^2, n	GY, kg/ha	AUDPC-PM
1.	NGRC 02306	142.5	840	1417.0
2.	NGRC 04003	183.5	3490	1060.5
3.	NGRC 04894	146.0	2955	1397.5
4.	NGRC 04902	196.0	2580	996.0
5.	NGRC 02306+NGRC 04003	178.0	3080	979.0
6.	NGRC 02306+NGRC 04894	106.0	2330	1330.5
7.	NGRC 02306+NGRC 04902	177.5	3385	1192.5
8.	NGRC 04003+NGRC 04894	150.0	3175	1067.0
9.	NGRC 04003+NGRC 04902	156.5	2855	993.5
10.	NGRC 04894+NGRC 04902	151.5	2920	1229.5
11.	NGRC 02306+NGRC 04003	142.0	2970	1033.0
12.	NGRC 04003+NGRC 04894+NGRC 04902	167.0	2830	1056.5
13.	NGRC 02306+NGRC 04894+NGRC 04902	134.5	2040	1153.5
14.	NGRC 02306+NGRC 04003+NGRC 04894	187.0	3580	976.5
	p-value	0.01	0.002	0.014
	LSD, 0.05	37.67548	890	252.15

GY, grain yield; PM, powdery mildew; AUDPC, area under disease progress curve.

Varietal mixture produced higher yield over sole system in all crops (buckwheat, finger millet, naked barley and bean) except rice (**Figure** 2). In addition to advantages of reducing disease infection and drought problem through mixture system, higher yield can be gained though this simple technology that ultimately support conservation of native crop diversity. Continue practices of mixing crop varieties increase the chance of creating better adapted genotypes and yield will keep increasing each season. Maintenance of seeds for next planting is also easy and farmers can themselves keep seeds, reducing the dependency on sourcing seeds as well as saving the money. Over the time, mixing ability of each component will be enhanced, ultimately producing higher yield, minimizing the risk of crop failure.

A growing number of studies show that, in natural ecosystems, functional diversity leads to higher stability (Petchey and Gaston 2002). Functional diversification can be achieved by using multilines, isolines and cultivar mixtures (Wolfe 1985). Mixing cultivars with more diverse genetic backgrounds than multilines can enhance functional diversity and improve yield by providing more chances for positive interactions among cultivars. Moreover, this offers better opportunities for on-farm conservation of genetic resources by allowing farmers to grow traditional cultivars. The use of cultivar mixtures is considered to be more practical and requires less investment than the use of multilines. This can be easily implemented by resource-poor farmers in developing countries - all that they have to do is mix existing cultivars with favorable agronomic traits and performance.

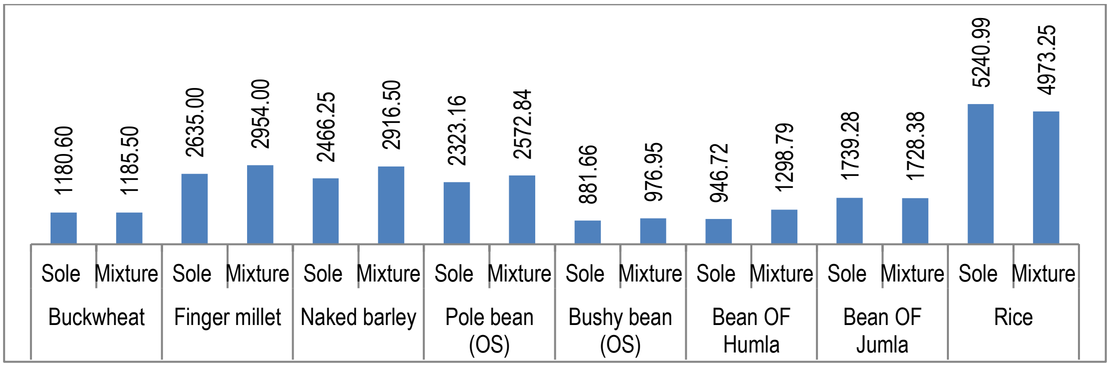

Figure 2. Grain yield (kg/ha) comparison between sole and mixture system in five crops.
OF, On-farm; OS, On-station.

Some constraints associated with cultivar mixtures are: a) prior knowledge of mixing ability of components, b) development of mixing and harvesting/processing technology, c) generation of seed production, mixing proportion of different cultivars and maintenance technology, d) unfavorable policy environment, e) how to release or integrate varietal mixture as new variety in national seed system, and f) poor knowledge on mechanism of reducing vulnerability in mixture.

Farmers' practices

Cultivar mixture is very old practice of mixing different landraces and varieties of different crops mainly of cereals, pseudo cereals and legumes. It has been practiced by many farmers in many areas across the country, however policy does not favor for the production and marketing of such inter varietal diversity. Farmers grow several cultivars in a field or adjacent field as a strategy to cope with heterogeneous and uncertain ecological and socioeconomic conditions. Different practices of mixing landraces adopted by farmers in Dolakha, Jumla and Kaski districts are given in **Table** 11. In many cases, farmers grow cultivars together mixing different proportion (randomly) of seeds of different varieties and landraces, harvest, store, cook, eat and market together. Jumli bean, which is a mixture of up to 20 different types of bean landraces is very common in Nepal.

Major crop mixtures (based on the interviewed with 15 farmers) are: proso millet + bean, potato + bean + pumpkin, maize + bean, bottle gourd + potato, pigeon pea + black gram + sorghum, mustard + lentil + pea + linseed, wheat + pea, maize + pumpkin + bean, maize + bean + cowpea, finger millet + soybean + horse gram, black gram + rice bean, maize + bean + cowpea + soybean + pumpkin, rice + black gram + soybean, wheat + pea + mustard, cauliflower + radish, maize + ginger + taro, finger millet + foxtail millet, proso millet + foxtail millet, maize + bean + potato + pumpkin, finger millet + cowpea + rice bean, finger millet + horse gram + black gram, etc.

Table 11. Farmers practices of cultivar mixture and their advantages

Crop	Mixing component	Site	Advantages
Bean	>20 landraces	Jumla	Less damage by diseases, 2-3 months continuous harvest, tasty
Finger millet	Dalle Kodo + Bhotyangre Kodo + Chyalthe Kodo	Jugu, Dolakha	Higher yield, good forage, less diseases
Rice	Kaali Maarsee+ Chandanaath-1 + Chandanaath-2	Jumla	Less damage by blast, taste remain as local landrace
Rice	Gurdhi + Mansaraa	Pame, Kaski	Better even under drought conditions, less damage by insect pests and diseases
Rice	Kaalo Paatle + Maachhaapuchhre + Lekaali	Dhikur Pokhari, Kaski	No damage by monkey, higher grain yield, less damage by disease, no lodging
Rice	1. Maanaa Muri + Saano Gurdhi, 2. Kaathe Dhaan + Panhele, 3. Thimaaha + Angaa + Mansaraa, 4. Kaalo Paatle + Chhomrong + Maachhapuchhre-3	Kaski	Lodging tolerant, less damage by insect pests and diseases, testy, higher grain yield

Source: Joshi et al 2018.

How cultivar mixture works

Diversifying the plots in terms of different traits eg different plant height, root length, plant structure, leaf texture, color, etc., creates a very diverse micro environment both at vertical and horizontal surface that helps utilize all space and nutrients available at different space, creates unfavorable environment for rapid growth of pathogens and insect pests, complements among individual plants to cope with different biotic and abiotic stresses. Mixing cultivars promotes functional diversification that limits mainly the development of diseases (**Figure** 3) as well as leads to higher stability (Petchey and Gaston 2002). Variation also helps prolong the useful life of resistance genes and increasing the crop productivity by taking into account the functional differences in disease resistance and other agronomic traits of cultivars. Conceptual diagram shown in **Figure** 4 is an example of rice landrace with total 208 stresses that need be tackled during seeding to harvesting to storage period. Variation in root length and plant height is the simple strategy to cope drought during crop growth period. Texture, size, structure, scent, color variation are useful to properly utilize the space and suppress the pathogens and insect pests. Different sizes of grains work in the similar way to suppress the storage pests. Genetically diverse seeds have different nutrient compositions and therefore eating together supplement nutrients each other making nutrition rich in total.

Cultivar mixture is a simple and sustainable genetic resources management system to increase yield, to conserve genes and to manage diseases effectively and efficiently (Castro 2001). For effectiveness of this system, general and specific mixing ability (GMA and SMA) of cultivars should be estimated. Similarly, cultivars and landraces should be selected based on maturity days, plant height and grain quality. Each genotype has unique agro-morphological traits, and DNA and isozymes bands. These agro-morphological traits and bands can be useful to make combination of cultivars and landraces.

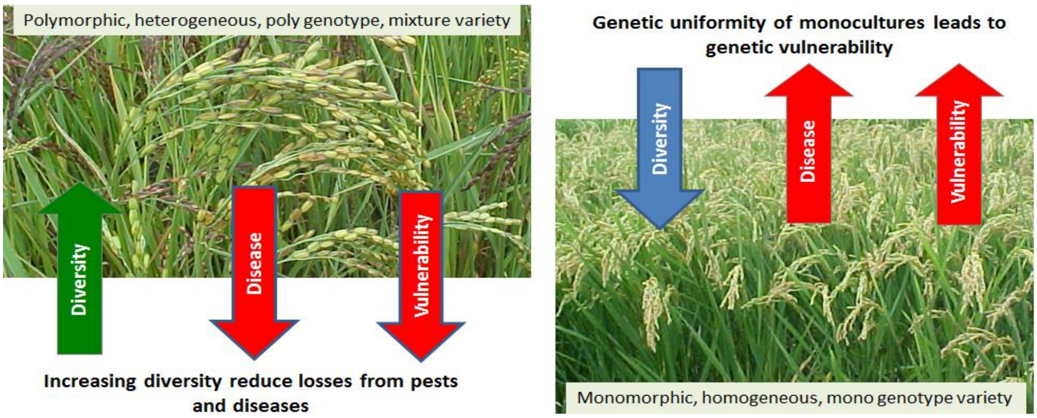

Figure 3. Diversity vs uniformity with regards to disease and vulnerability.

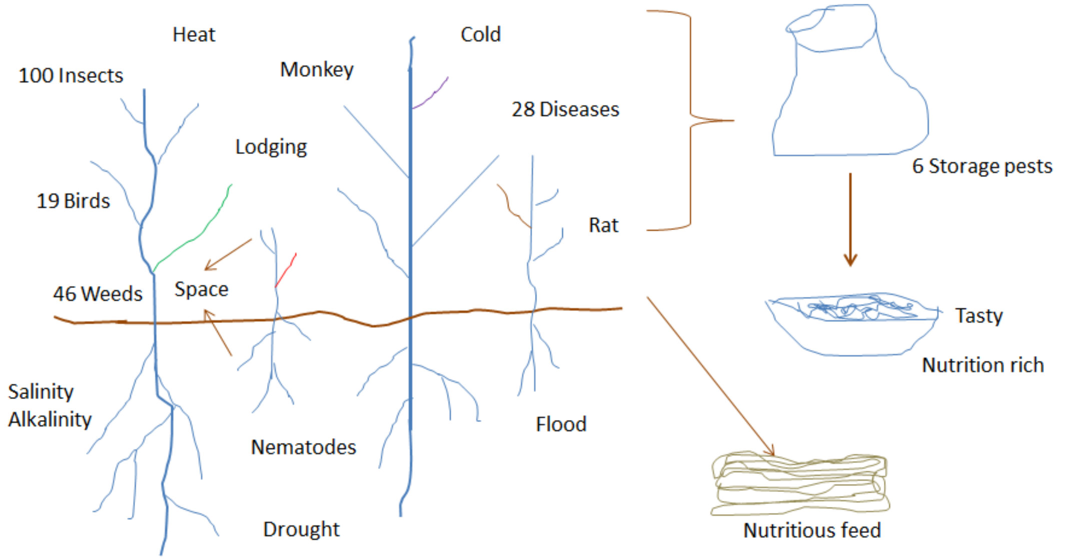

Figure 4. Conceptual working mechanism in cultivar mixture against different stresses and space utilization (rice as an example in the figure, 208 stresses are listed) along with the nature of products.

CONCLUSIONS

Cultivar mixture is a simple and low-cost technology that smallholders can easily adopt for different crops across the country. Growing different landraces together is a simple and sustainable genetic resources management system being practiced by farmers from ancient times, that help to increase yield, provide yield stability, to conserve genes and to manage diseases and other unpredictability factors (buffer against disease infection). Triblend and tetrablend multivars are generally and practically appropriate. In mixture, some traits may be enhanced and some suppressed. We need to consider multivar for managing abiotic and biotic factors (unpredictability factors) with low cost and knowledge rather than considering only yield. Research is needed to look on the mixing ability of varieties and landraces for identifying the better components mixture.

ACKNOWLEDGEMENTS

Support from farmers, NARC stations (ARS, Jumla and HCRP, Kabre) and project field staff (Kabita Jaisi, Dalaki Sherpa, Paras Mahat in Jumla; Hira Devi Hamal, Sundar Rawat in Humla; Narayan Dhami in HCRP; Surendra Shrestha and Safal Khatiwada in Kathmandu) are highly appreciated.

REFERENCES

Castro A. 2001. Cultivar mixtures. The Plant Health Instructor. **DOI**: 10.1094/PHI-A-2001-1230-01.

Finckh MR, ES Gacek H Goyeau, C Lannou, U Merz, CC Mundt, L Munk, J Nadziak, AC Newton, C Vallavieille-Pope and MS Wolfe. 2000. Cereal variety and species mixtures in practice, with emphasis on disease resistance. Agronomie **20**:813-837.

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages. Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, S Gyawali, SN Sah and RR Chaudhary. 2017. Competition among wild rice, landrace, improved cultivar and F_1 hybrid rice. The Journal of Agriculture and Environment **18**:32-42. https://www.nepjol.info/index.php/AEJ/article/view/19887/0

Joshi BK, SB Gurung, SP Vista, PB Paneru, R Gurung and S Pant. 2020a. Cultivar mixture. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**.65-70.

Joshi BK, RC Prasad, R Gurung, S Gautam, A Subedi, AR Adhikari, A Karkee and D Guchan. 2020b. Tradition of mixing bean landraces: Diversity rich solution for secured quality harvest and conservation in mountain agriculture. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Koizumi S. 2001. Rice blast control with multilines in Japan. In: Exploiting biodiversity for sustainable pest management (TW Mew, E Borromeo and B Hardy B, eds). Proc impact symposium on exploiting biodiversity for sustainable pest management, Kunming, China, 21-23 Aug 2000. International Rice Research Institute; **pp**.143-157.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhey, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis and BR Sthapit. 2016. A field guide for identification and scoring methods of diseases in the mountain crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.
Mundt CC. 2002. Use of multiline cultivars and cultivar mixtures for disease management. Annu. Rev. Phytopathol. **40**:381–410; **DOI**: 10.1146/annurev.phyto.40.011402.113723.
Palikhey E, S Gautam, S Sthapit, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2017. Baseline Survey Report: III. Haku, Jumla. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.
Petchey OL and KL Gaston. 2002. Functional diversity, species richness and community composition. Ecol. Lett. **5**:402-411.
Pradhanang PM and BR Sthapit. 1995. Effect of cultivar mixtures on yellow rust incidence and grain yield of barley in the hills of Nepal. Crop Protection **14**:331-334.
Sharma RC and HJ Dubin. 1996. Effect of wheat cultivar mixtures on spot blotch (*Bipolaris sorokiniana*) and grain yield. Field Crops Research **48**:95-101.
Zhu Y, H Chen, J Fan, Y Wang, W Li, J Chen, J Fan, S Yang, L Hu, H Leunak, TW Mewk, PS Tengk, Z Wanak and CC Mundt. 2000. Genetic diversity and disease control in rice. Nature **406**:718-722.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Performance of Bushy Bean Genotypes under Sole and Mixed Cultivation in Mountain Environment

Shree Prasad Vista, Netra Hari Ghimire, Paras Mani Mahat and Bal Krishna Joshi

ABSTRACT

Bean (*Phaseolus vulgaris* L.) is the major cash generating and protein-rich crop across mountain and hill of Nepal. Sole cropping of a landrace sometimes is havoc for producer particularly when outbreak or incidence of disease and insect pests prevails. Farmers generally prefer mixing of different varieties and landraces of crop to escape such havoc. An experiment was conducted at Agriculture Research Station, Vijayanagar, Jumla from 2016 to 2018 for three consecutive years to evaluate performance of bushy beans under sole and mixed cropping system against diseases and yield. The experiment was carried out for bushy beans in randomized complete block design with seven treatments replicated thrice. Treatments were both sole purelines and mixture of pure lines and traditional farmers' varieties. There was strong relationship between disease incidence (especially anthracnose and powdery mildew) and yield reduction of bushy bean. Sole cropping or mixing of KBL-5 with other varieties decreased the maturity days of the crop. Test weight was observed to be the highest in KBL-8 and lowest in KBL-5 in all the years. Higher yield was observed in KBL-5 but mixing of KBL-5 and PB-0001 showed synergistic increment in yield. Therefore, amongst the treatment combinations, it could be recommended to mix KBL-5 and PB-0001 for sustaining higher yield of bushy bean under the high mountain conditions.

Keywords: Bean mixture, bushy bean, mountain, production

INTRODUCTION

In the mid and the high mountains of Nepal, subsistence farming is the way of life. Such areas are rich in agrobiodiversity (Joshi et al 2020c) and farmers' preference for local crop is more because of their food habit and taste. Farmers in mountain areas mostly depend on their own crop landraces, as there are very limited number of modern varieties (Joshi et al 2017b). This, however, directly helps to conserve, protect and promote local crops. Bean (*Phaseolus vulgaris* L.) has been cultivated in 2250 ha of the land in Jumla district in 2014/15 (ARS 2014). There is large diversity of beans in mountains of Karnali province of Nepal and people consume soup of beans commonly known as 'dal' as dietary food. Bean is the major source of protein in Himalayan belt of Nepal (Joshi 2020d). Bean is an important cash crop in Jumla and adjoining high hill districts and Mustang where mixture of landraces with different size and seed coat color are harvested and sold in the market (Shrestha et al 2011, Joshi et al 2020b). It is mainly consumed as grain type in the mountain region. Farmers consider beans as a cash-generating crop and grow a number of landraces with varying morphology (Neupane 2003, Joshi et al 2020b). According to Neupane et al (2007), PB-0001 and PB-0048 were the varieties recommendable for Jumla conditions. Two varieties of bean are released so far but both of them are vegetable types (Joshi et al 2017b). Sole cropping of a crop sometimes is havoc for producer particularly when outbreak or incidence of disease and insect pests prevails. Therefore, farmers generally prefer mixing of different varieties of crop to escape such havoc. Cultivar mixture is one of the on-farm conservation simple method (Joshi and Upadhya 2019, Joshi et al 2020a) and has many advantages (Joshi et al 2018). Mixture practices can be adopted for different purposes (Joshi et al 2017a). In regard to this, we have conducted an experiment by mixing different species of bushy type bean for three consecutive years at Agriculture Research Station (ARS), Vijayanagar, Jumla with the objective to evaluate productive performance of bushy type bean under sole and mixed cropping system.

MATERIALS AND METHODS

The experiment was conducted in moderately deep to very deep and moderately to poor drained soil in ARS, Vijayanagar, Jumla. This research station is situated at an altitude of 2390 masl and thus is characterized by cool temperate to alpine eco-belts with low rainfall. The average maximum and minimum temperature are about 25^{0}C in June and 2^{0}C in February, respectively. Similarly, the average maximum rainfall of 250.6 mm was recorded in the past years while there was no rainfall in December. Surface soil and sub-surface soils are dominantly coarse-textured (sandy loam) and the soil is slightly acidic to neutral in reaction, high in extractable calcium, magnesium and available phosphorus; medium to low in organic matter, total N and available potassium. Three genotypes of bushy bean (PB-0001, KBL-5 and KBL-8) showing better performance were selected for this study. The experiment was carried out in randomized complete block design with seven treatments replicated thrice. Treatments adopted for the experiment were: sole PB-0001 (T_1), sole KBL-5 (T_2), KBL-8 (T_3), mixing of PB-0001, KBL-5 and KBL-8 (T_4), mixing of PB-0001 and KBL-5 (T_5), mixing of PB-0001 and KBL-8 (T_6) and mixing of KBL-5 and KBL-8 (T_7). The plot size was 6 meter square and the fertilizer dose of 60:40:40 of N, P_2O_5 and K_2O kg per hectare was applied. Nitrogen was applied as basal and top dress (50% each). The crop was grown with the best possible agronomic practices. Line sowing at 50 cm apart with two hand-weeding at different growth stages was done. Harvesting was done by cutting the whole crop and was threshed after drying. Different parameters were studied and yield was calculated at 12% moisture content. Disease scoring was based on Manandhar et al (2016). Data were analyzed using R software.

RESULTS AND DISCUSSION

Results of bushy type mixture trial on bean for three consecutive years are presented in Table 1, 2 and 3, respectively. In 2016, very low yield was recorded because of heavy rainfall and severe attack by anthracnose. Maturity days, test weight and anthracnose attack were significantly varied with the treatments. Maturity days was found earlier in KBL-5 by 12 days compared to PB-0001 and mixing KBL-5 with KBL-8 also decreased the maturity days to 76 days. Test weight was the highest (560 g) in KBL-8 comparatively and the lowest was in KBL-5 (347 g). Mixture of genotypes PB-0001 and KBL-5 gave the highest yield (754 kg/ha) followed by mixture of PB-0001, KBL-5 and KBL-8 (688 kg/ha) and mixture of PB-0001 and KBL-8 (676 kg/ha) (Table 1). There was strong relationship between disease incidence (especially anthracnose and powdery mildew) and drastic decrease in grain yield of bushy bean (Figure 1 and 2).

Table 1. Performance of bushy bean genotypes under sole and mix cropping at ARS, Jumla, 2016

Genotype	MD	PH	P/M^2	PD/PL	100Grain weight, g	Grain yield (kg/ha)	Anthracnose (0-9)	Powdery mildew (0-9)
PB-0001	86	39.7	32	6	51.0	634	5.0	3.3
KBL-5	74	32.3	39	6	34.7	634	7.0	5.7
KBL-8	78	33.7	31	4	56.0	396	7.0	5.0
1+2+3	79	36.7	31	8	46.3	688	5.0	4.3
1+2	77	38.3	32	7	38.0	754	5.0	3.3
1+3	81	39.3	29	6	49.7	676	4.3	3.3
2+3	76	30.3	32	4	39.0	369	5.0	3.7
F test	**	NS	NS	NS	**	NS	**	NS
CV, %	3.19	14.11	18.13	30.34	10.30	31.45	15.94	24.03
LSD (0.05)	4.46	-	-	-	8.24	-	1.55	-

MD, Maturity days; PH, Plant height; P/M², Plant per meter square; PD/PL, Number of pods per plant.

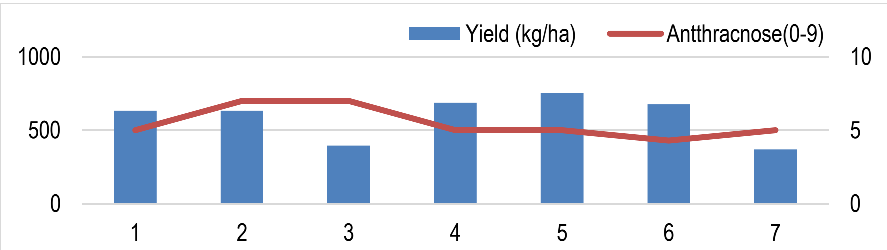

Figure 1. Relationship of yield and anthracnose infection in bushy bean, 2017.

Similarly, in 2017, heading days, maturity days, plant height, pod length, seed diameter, test weight and powdery mildew attack were significantly varied with the treatments. Maturity days was found earlier in KBL-5 by 12 days compared to PB-0001 and mixing KBL-5 with KBL-8 also decreased the maturity days to 76 days. Test weight was the highest (460 g) in KBL-8 and the lowest (233 g) in KBL-5. Mixture of genotypes PB-0001, KBL-5 and KBL-8) gave the highest yield (1198 kg/ha) followed by mixture of PB-0001 and KBL-5 (882 kg/ha) and sole crop of

PB-0001 (785 kg/ha) (Table 2). There was strong relationship between disease incidence (especially bean rust and mosaic virus) and reduction in grain yield of bushy bean (Table 2).

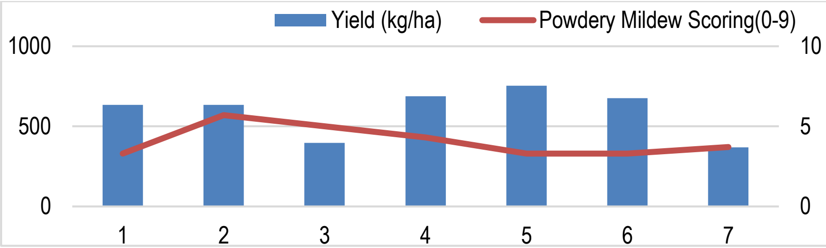

Figure 2. Relationship of yield and powdery mildew infection in bushy bean, 2016.

Table 2. Performance of bushy bean genotypes under sole and mix cropping at ARS, Jumla, 2017

GN	HD	MD	PH	PDL	PD/PT	SD/PD	HGW	GY	ANTH	BR	MV	PM
PB-0001	45	88	44.7	10.0	8	5	34.0	785.6	5	3	2	3
KBL-5	42	76	35.0	4.7	11	5	23.3	749.4	7	4	3	4
KBL-8	42	77	36.3	4.3	14	4	46.0	693.9	7	4	3	6
SOLE 1+2+3	44	81	41.3	14.0	7	5	34.0	1198.3	6	3	2	4
1+2	44	81	36.7	12.7	5	5	28.7	882.2	6	3	2	4
1+3	44	84	34.0	14.3	6	5	37.0	675.6	6	3	2	3
2+3	41	76	31.0	4.3	12	4	35.3	573.3	6	3	3	5
GM	43	81	37	9.19	9	5	34.0	794.05	6	3	2	4
F TEST	**	**	**	**	**	NS	**	NS	NS	NS	NS	**
LSD (0.05)	1.68	1.71	6.61	2.19	3.60	-	9.79	-	-	-	-	1.26
CV, %	2.2	1.2	10	13.4	22.8	10.4	16.2	39.5	18.9	19.4	18.3	17.5

HD, heading days; MD, maturity days; PH, plant height; PDL, pod length in cm; SD/PD, number of seeds per pod; HGW, 100 grain weight; GY, grain yield; ANTH, anthracnose; BR, bean rust; MV, mosiac virus; PM, powdery mildew.

In 2018 season, days to maturity and test weight were significantly differed with treatments. KBL-5, KBL-8 and mixture of both of these varieties matured earlier compared to other varieties and mixture. These results were found similar with earlier years' results. KBL-5 matured 15 days earlier to PB-0001. The results revealed that mixing of KBL-5 and KBL-8 reduces the maturity period by at least 12 days. KBL-5 was the highest yielder with 1890 kg/ha followed by mixture of KBL-5 and KBL-8 (1758 kg/ha) and mixture of PB-0001 and KBL-5 (1715 kg/ha) whereas the lowest yield (864 kg/ha) was of KBL-8. This variety was found very susceptible to anthracnose and powdery mildew (Table 3). Similar results were obtained by Prasad et al (2016). That is why, mixing of KBL-8 with other variety showed significantly increased disease incidence.

Table 3. Performance of bushy bean genotypes under sole and mix cropping at ARS, Jumla, 2018

Genotype	MD	PH	P/M²	PD/PL	100GW, g	Yield, kg/ha	Anthracnose (0-9)	Powdery mildew (0-9)
PB-0001	91	53.33	28	9	40.33	1288	3	6
KBL-5	76	52.33	34	7	28.33	1890	7	8
KBL-8	79	46.67	21	6	49.00	864	8	8
1+2+3	78	56.00	31	10	41.67	1361	4	5
1+2	86	57.67	26	10	36.00	1715	4	6
1+3	86	57.67	32	9	38.33	1073	5	6
2+3	77	48	29	7	42.00	1758	8	8
F test	***	NS	NS	NS	***	NS	*	*
CV, %	2.09	10.54	24.96	26.19	8.5	46.51	30.21	16.57
LSD (0.05)	3.05	9.87	12.69	3.97	-	1175.96	2.99	1.97

MD, maturity days; PH, plant height; P/M², plant per meter square; PD/PL, number of pods per plant; GW, grain weight.

Results of three consecutive years revealed that sole cropping or mixing of KBL-5 with other varieties decreased the maturity days of the crop. Test weight was observed to be the highest in KBL-8 and the lowest in KBL-5 in all years. Higher yield was observed in KBL-5 but mixing of KBL-5 and PB-0001 showed synergistic increment in yield. Therefore, amongst the treatment combinations, it could be recommended to mix KBL-5 and PB-0001 for sustaining higher yield of bushy bean under the high mountain conditions. These landraces were collected and selected by ARS, Jumla for registration, which have shown better performance among diverse landraces.

CONCLUSIONS

A strong relationship between disease incidence (especially anthracnose and powdery mildew) and yield reduction of bushy bean was observed. Sole cropping or mixing of KBL-5 with other varieties decreased the maturity days of the crop. Test weight was observed to be the highest in KBL-8 and lowest in KBL-5 in all the years. Amongst several combination of mixing genotypes, KBL-5 and PB-0001, was found the best option. In general, mixing of only two landraces showed better performance than mixing of three landraces. Therefore, amongst the treatment combinations it is recommended to mix KBL-5 and PB-0001 for higher yield of bushy bean under the high mountain conditions of Karnali province as well as to conserve different bean cultivars.

ACKNOWLEDGEMENTS

Authors would like to acknowledge project team and the National Genebank for continuous technical and moral support to prepare this manuscript. Field staff of ARS, Jumla are highly acknowledged for the field and technical work.

REFERENCES

ARS. 2014. Annual Report 2070/71. Agricultural Research Station, NARC, Bijayanagar, Jumla, Nepal.

Joshi BK and D Upadhya. 2019. On-farm conservation approaches for agricultural biodiversity in Nepal. Journal of Agriculture and Natural Resources **2**:14-35. **DOI**: https://doi.org/10.3126/janr.v2i1.26012

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages. Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal, and BR Sthapit. 2017b. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, Pokhara; NARC, Kathmandu and Bioversity International, Pokhara, Nepal.

Joshi BK, N Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020c. Agrobiodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020d. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, RC Prasad, R Gurung, S Gautam, A Subedi, AR Adhkari, A Karkee and D Gauchan. 2020b. Tradition of mixing bean landraces: Diversity rich solution for secured quality harvest and conservation in mountain agriculture. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, S Gyawali, SN Sah and RR Chaudhary. 2017a. Competition among wild rice, landrace, improved cultivar and F_1 hybrid rice. The Journal of Agriculture and Environment **18**:32-42.

Joshi BK, SB Gurung, SP Vista, PB Paneru, R Gurung and S Pant. 2020a. Cultivar mixture. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**.65-70.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhey, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis and BR Sthapit. 2016. A Field Guide for Identification and Scoring Methods of Diseases in the Mountain Crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

Neupane RK 2003. A summary of the first stakeholders' meeting on development of improved production technology of Phaseolus beans to the hills of mid-western Nepal, 22 June 2002 ARS, Jumla.

Neupane RK, R Shrestha, ML Vaidya, EM Bhattarai and R Darai. 2007. Agromorphological diversity in common bean (*Phaseolus vulgaris* L.) landraces of Jumla, Nepal. **In**: Proc. Fourth International Food Legumes Research Conference (IFLRC-IV) (MC Kharkwal, ed). 18-22 October 2005, New Delhi, India; **pp**.1-11.

Prasad RC, MN Paudel, NH Ghimire and BK Joshi. 2016. Cultivars mixtures in bean reduced disease infestation and increased grain yield under mountain environment of Nepal. Agronomy Journal of Nepal **4**:126-133.

Shrestha R, RK Neupane and NP Adhikari. 2011. Status and future prospects of pulses in Nepal. Paper presented at the Regional Workshop on Pulse Production held at Nepal Agriculture Research Council (NARC), Kathmandu; **pp**.1-28.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Projec, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Performance of Trailing type Bean Genotypes under Sole and Mixed Cultivation in Mountain Environment

Shree Prasad Vista, Netra Hari Ghimire, Paras Mani Mahat and Bal Krishna Joshi

ABSTRACT

Bean (*Phaseolus vulgaris* L.) is the major crop and growing beans by mixing different cultivars is common among farmers in the mountains of Nepal. Farmers generally practice mixing of different cultivars of bean to escape climate adversities and disease and pest incidence. An experiment was conducted at Agriculture Research Station, Vijayanagar from 2016 to 2018 for three consecutive years to evaluate productive performance of trailing type beans under sole and mixed cropping system. Results of three consecutive years revealed that though there was higher yield increment by mixing cultivars but no single combination was consistently high over years. Mixing of trailing-type bean cultivars showed synergistic increment in yield. Single combination could not be recommended based on these trials for higher yield of trailing bean under the mountain conditions. Additional research considering wide bean genotypes are needed for identifying the better cultivar mixture technology.

Keywords: Genotype mixture, mountain, trailing type bean

INTRODUCTION

In the mid and high mountain of Nepal, mix cultivation of crops is popular (Joshi et al 2020b, Joshi et al 2018). Mixing of different cultivars of bean has been practiced since long time and still the practice exists. Farmers have different experience of mixing cultivars in terms of yield, incidence of disease and pest, combating adverse effect of climate change and so on. Mountain areas are also rich in agrobiodiversity (Joshi et al 2020c) and farmers' preference to local crop is more because of their food habit and taste. Farmers in mountain areas mostly depend on their own crop landraces, as there are very limited number of modern varieties (Joshi et al 2017b). This, therefore, directly helps to conserve, protect and promote local crops. Bean (*Phaseolus vulgaris* L.) has been cultivated in 2250 ha of the land in Jumla district in 2014/15 (ARS 2014). There is large diversity of beans in Karnali zone of Nepal and people consume soup of beans as dietary food. Bean is the major source of protein in Himalayan belt of Nepal (Joshi et al 2020d). Bean is an important cash crop in Jumla and adjoining high mountain districts and Mustang where mixture of landraces with different size and seed coat color are harvested and sold in the market (Shrestha et al 2011, Joshi et al 2020b). It is mainly consumed as grain type. Farmers regard beans as a cash-generating crop and grow a number of landraces with varying morphology (Neupane 2003, Joshi et al 2020b). According to Neupane et al (2007), PB-0001 and PB-0048 were the varieties recommendable for Jumla conditions. Two varieties of bean are released so far but both of them are vegetable type (Joshi et al 2017b). Sole cropping of a crop sometimes is risky for producer particularly when outbreak or incidence of disease and insect pests prevails. Farmers also cultivate crop mixtures for enhancing taste while using as various food items. Therefore, farmers generally prefer mixing of different varieties of crop to escape risks and enhance quality of foods. Cultivar mixture is one of the on-farm conservation simple method (Joshi and Upadhya 2019, Joshi et al 2020a) and has many advantages (Joshi et al 2018). Mixture practices can be adopted for different purposes (Joshi et al 2017a). In this context, we have conducted an experiment by mixing different genotypes of trailing type bean at the Agriculture Research Station (ARS), Jumla with the objective to evaluate productive performance of trailing type bean under sole and mixed cropping systems.

MATERIALS AND METHODS

The experiment was conducted in moderately deep to very deep and moderately to poor drained soil in ARS, Vijayanagar, Jumla. This research station is situated at an altitude of 2390 masl and thus is characterized by cool temperate to alpine eco-belts with low rainfall. The average maximum and minimum temperature is about 25^{0}C in June and 2^{0}C in February, respectively. The average maximum rainfall of 250.6 mm was recorded in earlier years while there was no rainfall in December. Surface and sub-surface soils are dominantly coarse-textured (sandy loam) and the soil is slightly acidic to neutral in reaction, high in extractable calcium, magnesium and available phosphorus; medium to low in organic matter, total N and available potassium. Four genotypes of trailing type bean (PB-0002, KBL-1, KBL-2 and KBL-3) showing better performance were selected and used for the study. The experiment was carried out in randomized complete block design with twelve treatments replicated thrice and for three consecutive years. Treatments adopted for the experiment were: sole PB-0002 (T_1), sole KBL-1 (T_2), sole KBL-2 (T_3), sole KBL-3 (T_4), mixing of PB-0002, KBL-1, PBL-2 and KBL-3 (T_5), mixing of PB-0002 and KBL-1 (T_6), mixing of PB-0002 and KBL-2 (T_7), mixing of PB-0002 and KBL-3 (T_8), mixing of KBL-1 and KBL-2 (T_9), mixing of KBL-1 and KBL-3 (T_{10}), mixing of KBL-2 and KBL-3 (T_{11}), and mixing of KBL-1, KBL-2 and KBL-3 (T_{12}). The plot size was 6 meter square and the fertilizer dose of 60:40:40 of N, P_2O_5 and K_2O kg per hectare was applied. Nitrogen was applied as basal and top dress (50% each). The crop was grown with the best possible agronomic practices. Line sowing at 50 cm apart with two hand weeding at different growth stages was done. Harvesting was done by cutting the whole crop and was threshed after drying. Different parameters were studied and yield was calculated at 12% moisture content. Diseases scoring were based on Manandhar et al (2016). Data were analyzed using R-software.

RESULTS AND DISCUSSION

Results of trailing type bean mixture trial for three consecutive years are presented in **Table** 1, 2 and 3. In 2016, maturity days, test weight and powdery mildew attack were significantly varied (Prasad et al 2016). Maturity period was earlier in KBL-2 by a week compared to PB-0002 and mixing these two cultivars slightly reduced the maturity days. Test weight (100 grain weight) was the highest (420 g) in PB-0002 and the lowest (277 g) was in KBL-2. Sole cropping of KBL-2 was the highest yielder with 3274 kg/ha followed by mixture of KBL-1 and KBL-2 (3021 kg/ha), mixture of KBL-2 and KBL-3 (2966 kg/ha) and mixture of PB-0002, KBL-1, KBL-2 and KBL-3 (2862 kg/ha) (**Table** 1). There was no relationship between disease incidence especially anthracnose and powdery mildew and grain yield of trailing type bean in the first year.

Table 1. Performance of trailing type bean genotypes under sole and mix cropping at ARS, Jumla, 2016

TN	Treatment	DM	PH	P/M^2	PD/PL	100GW	Yield (kg/ha)	Anthrac-nose (0-9)	PM (0-9)
1	PB-0002	90	77.0	33	14	42.0	2065	0	3.3
2	KBL-1	85	72.7	39	15	28.0	2583	2	4.0
3	KBL-2	83	71.3	49	14	27.7	3274	1	3.0
4	KBL-3	90	82.0	32	12	33.3	2075	0	5.0
5	1+2+3+4	86	78.0	32	16	33.7	2862	0	4.3
6	1+2	90	68.7	31	14	35.0	2060	2	5.0
7	1+3	85	84.7	32	15	33.7	2568	2	3.3
8	1+4	89	85.7	37	15	39.0	2576	0	4.3
9	2+3	85	84.3	36	13	27.7	3021	2	6.3
10	2+4	89	75.3	35	16	27.0	2614	2	7.0
11	3+4	87	83.0	38	17	32.7	2966	0	5.0
12	2+3+4	87	79.0	32	14	31.7	2758	0	7.0
	F test	**	NS	NS	NS	**	**	-	**
	CV, %	1.63	11.07	16.18	21.23	6.33	14.25	-	22.31
	LSD (0.05)	2.41	-	-	-	3.49	631.70	-	1.82

TN, treatment number; DM, days to maturity; PH, plant height, cm; P/M^2, plant per meter square; PD/PL, number of pods per plant; GW, grain weight; PM, powdery mildew.

In 2017 season, the treatments showed significant differences in days to heading, days to maturity, pod length, test weight, and bean rust score. There were insignificant differences on grain yield, plant height and other studied parameters (**Table** 2). Mixture of PB-0002 and KBL-2 produced the highest yield (3312 kg/ha) followed by the mixture of KBL-1 and KBL-3 (2625 kg/ha) and the mixture of KBL-1, KBL-2 and KBL-3 (2615 kg/ha).

Table 2. Performance of trailing type bean genotypes under sole and mix cropping at ARS, Jumla, 2017

TN	Treatment	HD	MD	PH	PDL	PD/PT	SD/PD	HGW	GY	ANTH	BR	MV	PM
1	PB0002	50	90	99.1	13.6	8	6	31.3	2051.1	4	2	2	3
2	KBL-1	55	90	105	12.3	10	7	19.7	1882.2	4	3	2	3
3	KBL-2	56	87	88.5	13.2	11	6	21.7	2566.7	4	2	2	4
4	KBL-3	56	94	112	12.96	8	6	28.7	2358.3	4	2	2	3

TN	Treatment	HD	MD	PH	PDL	PD/PT	SD/PD	HGW	GY	ANTH	BR	MV	PM
5	SOLE 1+2+3+4	56	90	123	13.4	8	8	27.3	2447.8	4	2	2	3
6	1+2	51	89	106	13.46	9	7	29.0	2181.1	4	1	1	2
7	1+3	53	92	93.3	13.86	10	6	28.7	3312.2	3	2	1	3
8	1+4	54	93	105	14.26	11	6	32.7	2423.9	4	3	1	3
9	2+3	57	88	104	12.90	11	7	20.7	2538.9	4	3	2	3
10	2+3+4	56	92	109	13.13	10	7	23.3	2615.0	4	2	2	3
11	2+4	56	94	117	12.73	10	6	27.3	2625.6	4	2	1	3
12	3+4	56	92	100	13.20	9	6	22.7	2128.9	4	2	1	3
	F-test	**	**	NS	**	NS	NS	**	NS	NS	**	NS	NS
	LSD (0.05)	3.1	2.18		0.75			4.39			0.62		
	CV, %	3.3	1.4	12.2	3.4	17.7	12.2	9.9	20.8	31.6	16.7	33.4	28.6

TN, treatment number; HD, heading days; MD, maturity days; PH, plant height; PDL, pod length in cm; SD/PD, number of seeds per pod; HGW, 100 grain weight; GY, grain yield; ANTH, anthracnose; BR, bean rust; MV, mosaic virus; PM, powdery mildew.

In 2018 season, only test weight and days to maturity were differed significantly among the treatments (**Table** 3). Though not significantly different, mixture of KBL-2 and KBL-3 gave the highest yield (2768 kg/ha) followed by sole cropping of KBL-2 (2738 kg/ha). KBL-2 matured at least a week earlier compared to PB-0002 and mixing of KBL-2 with other cultivar reduced the maturity days of the mixture.

Table 3. Performance of trailing type bean genotypes under sole and mix cropping at ARS, Jumla, 2018

TN	Treatment	DF	DM	Plant height (cm)	Pod/plant	Seed/pod	100GW (g)	Yield (kg/ha)
1	PB0002	54	90ab	120.67	12	5	31.67ab	2078.61
2	KBL-1	54	88bcd	141.67	11	6	23.33bc	1835.63
3	KBL-2	55	83e	118.67	12	7	24.67abc	2737.78
4	KBL-3	55	93a	149.67	15	6	27.33abc	2370.65
5	SOLE 1+2+3+4	53	87bcde	113.67	13	6	31.33ab	2536.27
6	1+2	55	89abc	123.67	15	5	29.00abc	2243.09
7	1+3	57	86bcde	117.67	15	6	31.33ab	2521.47
8	1+4	55	93a	132.00	13	8	32.67a	2640.57
9	2+3	54	84de	132.00	14	7	20.33c	2522.06
10	2+3+4	54	93a	127.33	12	5	25.0abc	2207.76
11	2+4	54	87bcde	124.67	15	6	25.00abc	2610.15
12	3+4	55	85cde	110.00	15	7	22.33c	2768.28
	CV, %	3.96	1.71	13.54	27.75	28.93	10.82	15.49
	F-test	NS	**	NS	NS	NS	**	NS
	LSD (0.05)	-	5.14	--	--	--	5.14	

CONCLUSIONS AND RECOMMENDATIONS

A higher incremental yield was obtained by mixing cultivars but no single combination was consistently high over years. Mixing of trailing-type bean cultivars showed synergistic increment in yield. Single combination could not be recommended based on these trials for higher yield of trailing bean under the mountain conditions. For sustaining trailing type bean production under the high mountain conditions of Karnali province, mixing of genotypes could be one of the best options. This system is very common and old practices of farmers in Jumla. Though there was not consistency in the yields of genotypes mixture in different years and not significantly different on yield, mixture yield was higher compared to sole cropping due to potential benefits under adverse conditions. Additional research considering the use of wide bean genotypes are needed for identifying the better cultivar mixture technology for bean production in the mountains.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the National Genebank and its research team for continuous technical and moral support to prepare this manuscript. Field staff of ARS, Jumla are highly acknowledged for the field and technical work.

REFERENCES

ARS. 2014. Annual Report 2070/71. Agricultural Research Station, NARC, Bijatnagar, Jumla, Nepal.

Joshi BK and D Upadhya. 2019. On-farm conservation approaches for agricultural biodiversity in Nepal. Journal of Agriculture and Natural Resources **2**:14-35. **DOI**: https://doi.org/10.3126/janr.v2i1.26012

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages.

Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal, and BR Sthapit. 2017b. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, Pokhara; NARC, Kathmandu and Bioversity International, Pokhara, Nepal. https://www.bioversityinternational.org/fileadmin/user_upload/Released_and_promising_crop_varieties.pdf

Joshi BK, N Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020c. Agrobiodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020d. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, RC Prasad, R Gurung, S Gautam, A Subedi, AR Adhkari, A Karkee and D Gauchan. 2020b. Tradition of mixing bean landraces: Diversity rich solution for secured quality harvest and conservation in mountain agriculture. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, S Gyawali, SN Sah and RR Chaudhary. 2017a. Competition among wild rice, landrace, improved cultivar and F_1 hybrid rice. The Journal of Agriculture and Environment **18**:32-42. https://www.nepjol.info/index.php/AEJ/article/view/19887/0

Joshi BK, SB Gurung, SP Vista, PB Paneru, R Gurung and S Pant. 2020a. Cultivar mixture. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**.65-70.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhey, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis and BR Sthapit. 2016. A Field Guide for Identification and Scoring Methods of Diseases in the Mountain Crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

Neupane RK. 2003. A summary report of the first stakeholders' meeting on development of improved production technology of Phaseolus beans to the hills of mid-western Nepal, 22 June 2002 ARS, Jumla.

Neupane RK, R Shrestha, ML Vaidya, EM Bhattarai and R Darai. 2007. Agromorphological diversity in common bean (*Phaseolus vulgaris* L.) landraces of Jumla, Nepal. In: Proc. Fourth International Food Legumes Research Conference (IFLRC-IV) (MC Kharkwal, ed). 18-22 October 2005, New Delhi, India; **pp**.1-11.

Prasad RC, MN Paudel, NH Ghimire and BK Joshi. 2016. Cultivars mixtures in bean reduced disease infestation and increased grain yield under mountain environment of Nepal. Agronomy Journal of Nepal **4**:126-133. https://www.nepjol.info/index.php/AJN/article/view/15535

Shrestha R, RK Neupane and NP Adhikari. 2011. Status and future prospects of pulses in Nepal. Paper presented at the Regional Workshop on Pulse Production held at Nepal Agriculture Research Council (NARC), Kathmandu; **pp**.1-28.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Climate Change Trends and Disease Situations in Some Major Traditional Crops in the Mountains of Dolakha, Lamjung, Jumla and Humla, Nepal

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ABSTRACT

Trend analysis of climatic parameters suggests that Nepal is more vulnerable to climate change; thus, a changing climate might have impact on plant disease occurrence and severity. This work aims to analyze the climate change pattern and its effect on occurrence and severity of disease of traditional crops and future scenario at the study sites. The study starts with an analysis of the last 29-31 years of climatic data from Simikot, Dipalgaun, Khudibazzar and Jiri of Humla, Jumla, Lamjung and Dolakha districts, respectively. Mann-Kendall and Sen's slope method have been used for the trend analysis and quantification. Data on local crop diseases assessed at diversity blocks, observation trials, seed production plots, evaluation trials, etc conducted at Chhipra, Hanku, Ghanpokhara and Jungu villages of Humla, Jumla, Lamjung and Dolakha districts, respectively during 2015-2017, were used for analysis. The results showed an increase in temperature of approximately 0.03ºC to 0.11ºC per year in different locations and a mixed trend in precipitations. Different diseases with varying severity were found on grain amaranth, naked barley, beans, buckwheat, fingermillet, foxtailmillet, prosomillet and rice in the study sites. There has been limited research on impact of climate change on local crops diseases in Nepal. Therefore, investigations on incidence and severity of plant diseases over time especially of traditional crops, in relation with climate change are highly recommended.

Keywords: Climate change, climatic parameters, impact, local crop diseases

INTRODUCTION

More than 60% of the population in Nepal, is dependent on agriculture (CBS 2013), which contributes 27.6% of the gross domestic product (MoF 2017/18). Thus, agriculture is regarded as a major contributor to the national economy as well as livelihood of the Nepalese people. Several cereal crops are cultivated in Nepal (Updhyay and Joshi 2013, Joshi et al 2020); however, five major crops, ie, rice, maize, wheat, fingermillet and barley, dominate the agricultural sector (Gumma et al 2013). Agricultural production and productivity are primarily dependent on climatic factors, and the favorable climatic conditions are well known to be crucial in generating optimal crop yield (Poudel and Kotani 2013). The climate of Nepal varies greatly from south to north because of the vast altitudinal variations, within a short span of about 193 km, altitudes ranging from 60 to 8848 m above mean sea level, giving the country diverse agro-ecological zones-mountains, hills and Tarai (DHM 2015). Nepal's climate is influenced by the Himalayan mountain range and the South Asian monsoon (NCVST 2009).

A rapid change in climate patterns potentially driven by global warming is considered to be greatest threats to agriculture (Poudel and Kotani 2013).Nepal has experienced an average maximum annual temperature increase of 0.06ºC (Shrestha et al 1999) with 0.09ºC in the Himalayan region (Practical Action 2007) and 0.04°C in theTarai belt (Practical Action 2007, Shrestha et al 1999). Similarly, it is expected that winter temperature will increase faster than summer temperature and the level of winter rainfall is likely to fall while level of summer rainfall is possible to increase. Likewise, there are more likely to have extreme and frequent hit waves and rainfalls (Practical Action 2007). Insufficient rain and increasing temperature cause drought, whereas intense rain in short period reduces ground water recharge by accelerating run-off and causes floods. Both the situations induce negative effects in the agriculture (Malla 2008). Agricultural productivity can be affected by climate change in two ways: first, directly due to changes in temperature, precipitation and/or CO^2 levels and second, indirectly through changes in soil and occurrence of pests including plant diseases (Lama and Devkota 2009).

Plant diseases are one of the important factors which have a direct impact on global agricultural productivity and climate change will further aggravate the situation (IPCC 2007) or may have positive, negative or neutral impact

(Chakraborty et al 2000).All phases of disease cycle, from the germination of spores to the development of lesions, are considerably influenced by climatic factors (temperature, humidity, precipitation, or deposition of dew). These factors may be modified by climate change (Bevitori and Ghini 2014). Lonsdale and Gibbs (1996) made the point that environmental change, especially when combined with pathogen and host introductions, may result in unprecedented effects. Climate change is just one of the many ways in which the environment can move in the long-term from disease-suppressive to disease-conducive or vice versa (Baker et al 2000). Therefore, plant diseases could be even used as indicators of climate change (Logan et al 2003).

Ghanpokhara, one of the study sites, lies at the altitude ranging from 850 to 6,983 masl in the high hill of Lamjung district. However, settlements are only found between 850 and 2175 masl where rice is the major cereal crop followed by fingermillet and crops like foxtail millet, barley, naked barley and amaranth are less grown by the farmers (Gurung et al 2016).Jungu lies at 950 to 3000 masl in the north-eastern region of the Dolakha district, where rice, wheat, maize, finger millet, buckwheat, and barley are the major cereal crops and beans are consumed as green vegetables (Pudasaini et al 2016). Hanku (2000 to 4600 masl) lies in the high hill of Jumla district, where rice, barley and finger millet are the major cereal crops and beans are mostly consumed as dry pulse rather than green vegetables (Palikhey et al 2016). Chhipra at the altitude of 2000-4800 masl is situated near the middle of Humla district, where fingermillet is the number one crop followed by barley, naked barley, wheat and rice (Parajuli et al 2016).

One of the basic tools to understand climate change is to analyze climate change from atmospheric observation (DHM 2017).Therefore, the objective of this studywas to analyze time series data of precipitation and temperature recorded by DHM at the nearest points to Chhipra, Hanku, Ghanpokhara and Jungu of Humla, Jumla, Lamjung and Dolakha districts, respectively and relate the climate change pattern with the occurrence and severity of diseases on local crops. This work aims to analyze the climate change pattern and its effect on occurrence and severity of major diseases of traditional crops and future scenario at the study sites.

MATERIALS AND METHODS

Study sites

Chhipra, Hanku, Ghanpokhara and Jungu of Humla, Jumla, Lamjung and Dolakha districts respectively, were the study sites for this study.

Climatic data

Meteorological data obtained from meteorological station of Khudibazzar (Lamjung), Jiri (Dolakha), Dipalgaun (Jumla)and Simikot (Humla) (**Figure** 1); maintained by the Department of Hydrology and Meteorology (DHM); wereutilized for this study (**Table** 1). Monthly average temperatures and relative humidity (%) were calculated by averaging the value of the month whereas annual average temperatures (maximum and minimum) and relative humidity (%) were calculated by averaging twelve months value of the year. Monthly rainfall was calculated by adding the amount of rainfall occurred within the months and annual rainfall was calculated by adding the amount of rainfall occurred within the year.

Table 1. Location of the meteorological stationsfrom where the data were obtained for the study

Location (District)	Latitude	Longitude	Elevation	Number of years
Khudibazar (Lamjung)	28.28333º	84.36667º	0823m	30 (1988-2017)
Jiri (Dolakha)	27.63333º	86.23333º	2003m	30 (1988-2017)
Dipalgaun (Jumla)	29.26667º	82.21667º	2310m	31 (1987-2017)
Simikot (Humla)	29.96667º	81.83333º	2800m	29 (1989-2017)

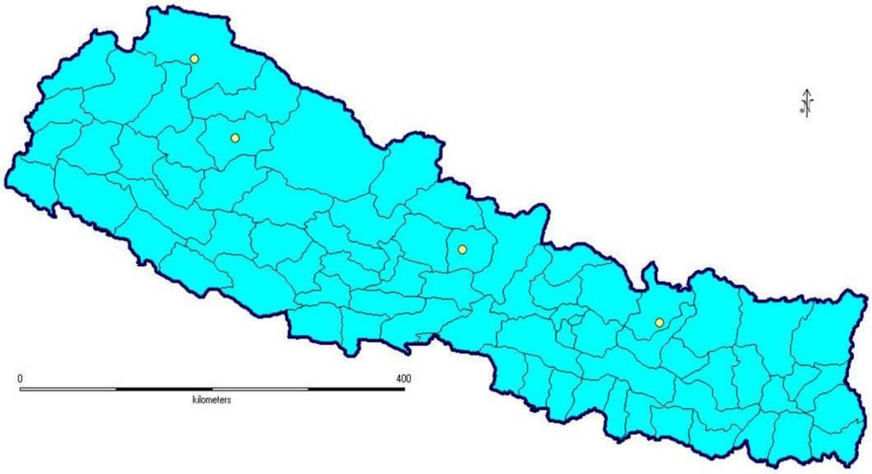

Figure 1. Study sites and location of meteorological station inHumla, Jumla, Lamjung and Dolakha districts.

Crop disease assessments at the study sites

Diseases on different local crops were assessed on diversity blocks, observation trails, seed production plots etc from 2014 to 2018 in different seasons at the study sites. Disease scoring was done as per the guidelines provided by the project, which was published later as a field guide (Manandhar et al 2016). For this study, the disease scores were converted to very low, low, medium and high disease severity. Disease information from secondary sources ie baseline survey of the study sites, travel reports, journal articles etc were also used.

Trend analysis of climatic data

The seasonal and annual trends were analyzed for the climate variables: temperature (monthly and annual maximum and minimum), precipitation (monthly and annual accumulated quantities) and relative humidity (monthly and annual average). Trend analysis is the prediction of future outcomes by using historical results (Bhuyan et al 2018). The existence of positive or negative trends among all the considered variables was determined using non-parametric trend test methods (Poudel and Shaw 2016). Combined Mann-Kendall test and Sen's slope method were used to analyze type, magnitude and significance of trend in climate time series data. Increasing or decreasing trend of all the independent weather parameters were statistically examined in two phases. First one is the using of non-parametric Mann-Kendall test and second one is the non-parametric Sen's slope estimator (Bhuyan et al 2018). In particular, Mann-Kendall technique can be adopted in cases with non-normally distributed time series data, that is, data containing outliers and non-linear trends (Karpouzos et al 2010). The increasing or decreasing trends was tested based on normalized test statistics (Z) value. When Z is positive, trend is said to be increasing and when Z is negative, it is said to be decreasing. The trend's slope gives the annual rate and direction of change (Salmi et al 2002). In this study, MS-Excel program called MAKESENS version 1.0 developed by FMI in 2002 (Salmi et al 2002) was used to calculate magnitude, and Sen's slope method for trend analysis. The detail calculation method is explained by Salmi et al (2002).

RESULTS

Average climatic parameters over the years

The highest average maximum and minimum temperatures were observed in summer (June, July and August) months whereas the lowest average maximum and minimum temperatures observed in winter (December, January and February) months in all the study sites (**Figure** 2, 3, 4 and 5). Sweeney et al (2008) also reported that the low land of Nepal has average temperatures around 22-27°C in summer months and dropping down to 10-15°C in winter whereas the high altitude mountainous regions have average temperatures around 5-15°C during summer and fall considerably below 0°C in the winter months. In Simikot, maximum average temperature ranged from 14.5°C in January to 24.4°C in June and minimum average temperature ranged from -1.5°C in January to 17.2°C in July (**Figure** 2). In Dipalgaun, the average maximum temperature ranged from 14.0°C in January to 27.1°C in June and average minimum temperature ranged from -4.6°C in January to 14.9°C in July (**Figure** 3). In Khudibazzar, average maximum temperature ranged from 21.0°C in January to 31.2°C in June and average minimum temperature ranged from 7.3ºC in January to 21.7ºC in July (**Figure** 4). In Jiri, average maximum temperature ranged from 14.5ºC in January to 24.4ºC in June and average minimum temperature ranged from -1.5ºC in January to 17.2ºCin July (**Figure** 5).

In Nepal, monsoon rainfalls appear in the June and remain until August and September (Sweeney et al 2008) and 80percent of the precipitation that falls in Nepal comes in the form of summer monsoon (HMGN/MFSC 2002). Similar results were found in all locations that maximum rainfall occurs during June - September whereas the lowest rainfall occurs during November-December in the study sites (**Figure** 2, 3, 4 and 5). Sweeney et al (2008) also reported that monsoon rainfall brings about 250-450 mm of rainfall per month in most parts of the country except north-western mountain region, which only brings 100-150 mm rainfall on an average but other seasons have average rainfall well below 50mm in all parts of Nepal. Among the four locations the highest average annual rainfall occurs at Khudibazzar (3286.2mm) followed by Jiri (2458.2 mm), Dipalgaun (876.6 mm) and Simikot (784.0 mm) (**Figure** 3, 4, 5 and 6). Nepal's average annual rainfall is approximately 1800 mm but there are marked spatial and temporal variations both north-south and east-west and the monsoon rain is most abundant in the east and declines westwards (Practical Action 2009), while winter rains are more common and higher in the northwest (DHM 2015,Practical Action 2009) and declines south-westwards (Practical Action, 2009). At Simikot, the highest average rainfall (148.2 mm) occurred in August whereas the lowest average rainfall (14.2 mm) occurred in November (**Figure** 2). At Dipalgaun, the highest average rainfall (222.8 mm) occurred in July and the lowest average rainfall (4.0 mm) occurred in November (**Figure** 3). At Khudibazzar, the highest average rainfall (148.2 mm) recorded in August whereas the lowest rainfall (14.2 mm) recorded in November (**Figure** 4). At Jiri, the highest average rainfall (624.4 mm) recorded in July and the lowest average rainfall (8.3 mm) occurred in December (**Figure** 5).

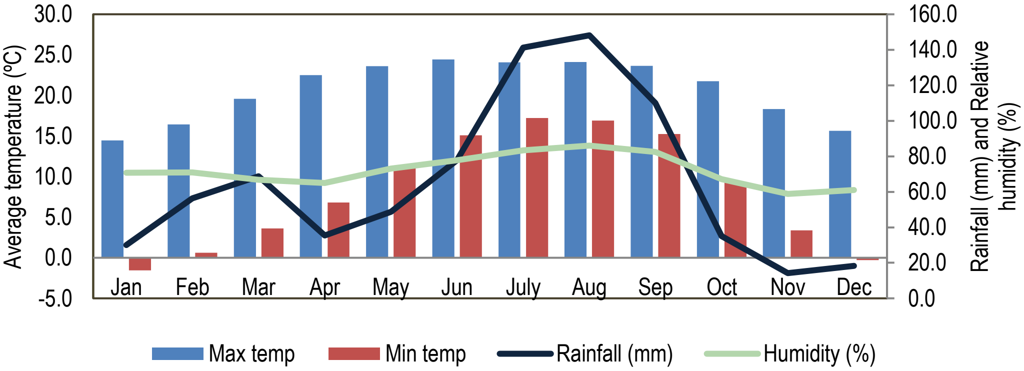

Figure 2. Average maximum and minimum temperatures (ºC), average monthly rainfall (mm) and average relative humidity (%) recorded for 29 years from 1989 to 2017 at Simikot.

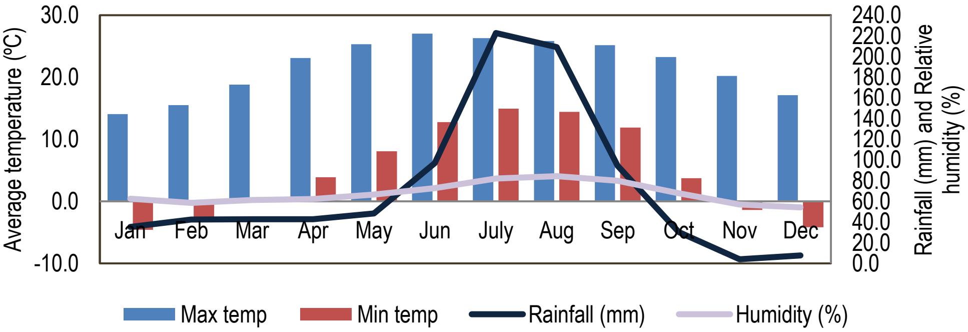

Figure 3. Average maximum and minimum temperatures (ºC), average monthly rainfall (mm) and average relative humidity (%) recorded for 31 years from 1987 to 2017 at Dipalgaun.

The highest average humidity (86.02%) in August and the lowest average humidity (58.18%) in November were recorded at Simikot, Humla (**Figure** 2). Similarly, average humidity (84.34%) in August and the lowest average humidity (54.18%) in December were recorded at Dipalgaun, Jumla (**Figure** 3). In Khudibazzar, Lamjung, the highest average humidity recorded was 86.8% in August and the lowest average humidity was 61.0% in April (**Figure** 4). In Jiri, Dolakha the highest average humidity was 89.4% in August and the lowest average humidity was 70.4% in April (**Figure** 5).

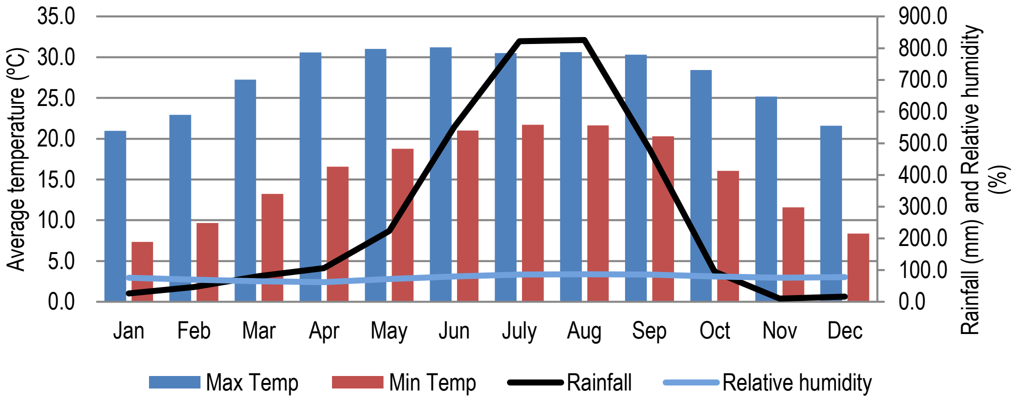

Figure 4. Average maximum and minimum temperature (°C), average monthly rainfall (mm) and average relative humidity (%) recorded for 30 years from 1988 to 2017 at Khudibazzar.

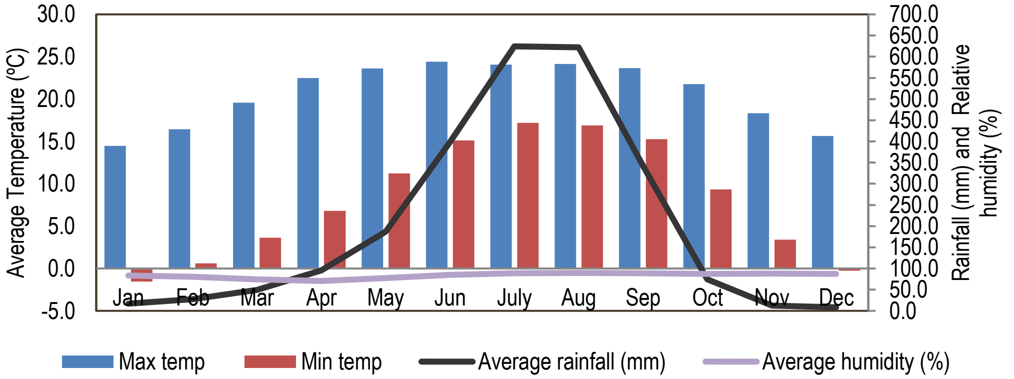

Figure 5. Average maximum and minimum temperature (°C), average monthly rainfall (mm) and average humidity (%) recorded for 30 years from 1988 to 2017 at Jiri, Dolakha.

Changing trends in climatic parameters

The annual maximum temperature wasin increasing trends in all study sites; the trend was the highest in Simikot (0.111°C/year) followed by Khudibazzar (0.049°C/year), Dipalgaun (0.043°C/year) and Jiri (0.030°C/year).The annual minimum temperature was found in highly increasing trendin Simikot (0.314°C/year) followed by Jiri (0.031°C/year) and Khudibazzar (0.013°C/year) (**Table** 2).In Dipalgaun, the trend was found decreasing by 0.008°C per year (**Table** 3). DHM (2017) also stated that seasonal and annual time series of maximum temperature of Nepal shows increasing trend. The mean temperature during 1971-2014 was increased with an average of 0.056°C per year but that increases varied from place to place.

Monthly Mann-Kendall trend and Sen's slope for maximum and minimum temperatures are shown in **Table** 2 and 3, respectively. AtSimikot, the maximum temperature was increased significantly in April (P>0.05), October (P>0.1), November (P>0.01) and December (P>0.1) (**Table** 2) and the minimum temperature was increased in April (P>0.1) and September (P>0.1) (**Table** 3). At Dipalgaun, months with significant increase in maximum temperatures were March (P>0.1), April (P>0.05), August (P>0.01), September (P>0.05), November (P>0.05), and December (P>0.05) (**Table** 2) and the minimum temperature was decreased significantly in August

(P>0.05).At Khudibazzar,months with significant increase in maximum temperatures were January (P>0.05), February (P>0.001), March (P>0.01), September (P>0.05) and December (P>0.05) (**Table** 2) and the minimum temperature increased inDecember (P>0.05) (Table 3).At Jiri, the maximum temperatures was increased significantly in February (P>0.05), August (P>0.01), September (P>0.05), November (P>0.05) and December (P>0.01) (**Table** 2) and the minimum temperatures was increased in April (P>0.01), October (P>0.1) and November (P>0.05) (**Table** 3). Likewise, significance of the maximum and minimum temperature trend was assessed using Mann-Kendall test, where negative and positive Z-values denoted downward (decreasing) or upward (increasing) trends of maximum (**Table** 2) and minimum (**Table** 3) temperatures.

Annual rainfall was decreased by 12.37 mm per year in Khudibazzar followed by Dipalgaun (4.252 mm/year) and Simikot (3.467 mm/year) but in Jiri, it was increased by 8.847 mm per year (**Table** 4).The result of Khudibazzar was somehow similar to the result obtained by Poudel and Shaw (2016) from the meteorological data studied in-between 1980 to 2012. Monthly Mann-Kendall trends and Sen's slope for rainfall are shown in **Table** 4. Monthly rainfall significantly was increased in January (P>0.1) at Simikot, in October (P>0.1) at Khudibazzar, and in October (P>0.05) at Jiri but decreased in February (P>0.1), June (P>0.1), August (P>0.01), November (P>0.1) and December (P>0.01) at Khudibazzar and in November (P>0.05) at Jiri (**Table** 4). Negative or positive Z-valuesof Mann-Kendall test showed decreasing or increasing rainfall pattern, respectively for each month at the study sites (**Table** 4). Both at district and physiographic level- insignificant decrease in monsoon precipitation in majority of districts east of 84°E longitude, and decreasing rainfall trend in all seasons in the high mountains and insignificant positive trend in all seasons, except in post-monsoon, in Taraihave been reported by DHM (2017). These coherent but insignificant patterns might be associated with short term variability in atmospheric phenomena (DHM 2017).Average Mann-Kendall trends and Sen's slope for relative humidity are shown in **Table** 5.Relative humidity (%)at Simikot was increased significantly in January (P>0.1), May (P>0.1), July (P>0.1) and October (P>0.1). At Dipalgaun, relative humidity was significantly increased in January (P>0.05), February (P>0.1), May (P>0.05) and December (P>0.05) decreased in July (P>0.05) and August (P>0.001). At Khudibazzar, significant increase in relative humidity was in July (P>0.05) and November (P>0.1).At Jiri, relative humidity was increased significantly in April (P>0.1), June (P>0.1), July (P>0.01), August (P>0.001), September (P>0.001) and October (P>0.001).

Diseases and their severities recorded on local crops

Finger millet diseases: Blast (*Pyricularia grisea*) in fingermillet was found low to medium in severity at Chhipra, Hanku and Ghanpokhara but Cercospora leaf spot (*Cercospora eleusine*) was high to medium in severity at Ghanpokhara and low in Jugu (**Table** 6). During the baseline survey at Chhipra, Ghanpokhara and Jugu, farmers stated that blast and Cercospora leaf spot were the major disease problems but in Chhipra, stem rot (pathogen not specified) and leaf blight (pathogen not specified) were the major disease problems (Parajuli et al 2016, Gurung et al 2016, Pudasaini et al 2016).

Rice diseases: Blast (*Pyricularia oryzae*) in rice was found in higher severity in Hanku, medium to high severity in Ghanpokhara and Jugu (**Table** 6). During baseline survey, blast of rice in all locations and sheath blight (*Rhizoctonia solani*) in cold tolerant rice at Hanku were found major diseases of rice (Parajuli et al 2016, Palikhe et al 2016, Gurung et al 2016, Pudasaini et al 2016).

Bean diseases: Angular leaf spot (*Isariopsis griseola*) was found with low to medium severity at Ghanpokhara and Jugu and medium to high severity in Chhipra and Hanku. Anthracnose (*Colletotrichum lindemuthianum*) was low to medium in severity at Chhipra, Hanku and Jugu but low severity in Ghanpokhara. Rust (*Uromyces appendiculatus*) was found with low to medium severity at Hanku and medium to high severity at Ghanpokhara. White mold (*Sclerotinia sclerotiorum)* was found in medium to higher severity at Hanku. Likewise, virus and virus-like diseases were also recorded at Hanku, Ghanpokhara and Jugu with low to high severity (**Table** 6). Anthracnose at Chhipra and Hanku; rust at Chhipra, Hanku and Jugu; angular leaf spot atHanku and viral diseases at Jugu were found major diseases during base line survey (Parajuli et al 2016, Palikhe et al 2016, Gurung et al 2016, Pudasaini et al 2016).

Grain amaranth diseases: Anthracnose (*Colletotrichum gloeosporioides*) and Cercospora leaf spot (*Cercospora canescens*) diseases of grain amaranths were found low severity in Hanku but not recorded in other locations (Table 6).

Buckwheat diseases: Powdery mildew (*Erysiphe polygoni*) with very low severity was found in Jugu (Table 6) but downy mildew (*Perenospora fagopyri*) at Chhipra and Hanku were major diseases of buckwheat during baseline survey (Parajuli et al 2016, Palikhe et al 2016).

Proso millet diseases: Blast (*Pyricularia grisea*) was found with low severity at Chhipra, Hanku and Jugu and headsmut (*Sphacelotheca destruens*) was found with low severity at Chhipra (Table 6). Leaf blight (*Bipolaris* sp.) was found major disease during base line survey at Chhipra (Parajuli et al 2016).

Foxtail millet diseases: Blast (*Pyricularia setariae*) was found with medium severity at Hanku and very low severity at Ghanpokhara. Leaf blight (*Bipolari* sp.) was low to medium in severity at Hanku (Table 6). Smut (*Ustilago crameri*) was the major disease at Chhipra during baseline survey (Parajuli et al 2016).

Naked barley diseases: Barley stripe (*Helminthosporium gramineum*) with medium severity, powdery mildew (*Blumeria graminis* f. sp. *hordei*) with medium to high severity; spot blotch (*Bipolaris sorokiniana*) with low severity and covered smut (*Ustilago hordei*) with very low severity were found at Ghanpokhara (Table 6). During baseline survey, loose smut (*Ustilago nuda*), rust (*Puccinia* spp.) and blight at Chhipra (Parajuli et al 2016), loose smut and yellow rust at Hanku (Palikhe et al 2016) and yellow rust and barley stripe at Jungu (Pudasaini et al 2016) were major diseases.

Table 2. Mann-Kendall trend test and Sen's slope estimate of monthly and annual average maximum temperature at Simikot, Dipalgaun, Khudibazzar and Jiri during 1978-2017

Month	Simikot		Dipalgaun		Khudibazzar		Jiri	
	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope
January	0.91	0.050	1.05	0.063	2.84	0.100**	1.59	0.042
February	0.40	0.038	1.26	0.068	3.34	0.100***	2.45	0.087*
March	0.74	0.105	1.77	0.092+	2.93	0.100**	1.45	0.033
April	2.00	0.202*	2.03	0.088*	0.26	0.010	0.73	0.014
May	0.00	0.000	-0.99	-0.033	-0.11	0.000	0.26	0.002
June	0.21	0.004	0.88	0.029	0.09	0.000	1.50	0.020
July	-0.11	0.000	1.30	0.033	0.18	0.000	1.31	0.011
August	-0.27	0.000	2.82	0.065**	1.63	0.026	2.83	0.027**
September	0.88	0.026	2.25	0.065*	2.24	0.049*	2.48	0.029*
October	1.79	0.093+	0.24	0.008	1.45	0.035	0.97	0.010
November	3.22	0.127**	1.96	0.093*	0.62	0.016	2.30	0.041*
December	1.93	0.214+	2.10	0.100*	2.24	0.063*	2.90	0.055**
Annual average	0.31	0.111	2.27	0.043*	2.82	0.049**	3.06	0.030*

*+α, 0.1 level of significance; *α, 0.05 level of significance; **α, 0.01 level of significance; ***α, 0.001 level of significance.*

Table 3. Mann-Kendall trend test and Sen's slope estimate of monthly and annual average minimum temperature at Simikot, Dipalgaun, Khudibazzar and Jiri during 1978-2017

Month	Simikot		Dipalgaun		Khudibazzar		Jiri	
	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope
January	-0.05	-0.009	0.70	0.023	-0.21	0.000	-0.29	-0.007
February	-0.05	-0.033	0.52	0.037	1.41	0.054	0.91	0.029
March	0.41	0.045	-0.07	0.000	0.23	0.007	1.59	0.043
April	1.81	0.112+	1.35	0.041	-0.54	-0.008	2.99	0.085**
May	0.81	0.073	0.38	0.014	-1.11	-0.020	-0.23	-0.009
June	0.72	0.061	-0.75	-0.023	-0.34	0.000	-0.11	0.000
July	0.50	0.027	-1.40	-0.023	0.88	0.008	0.97	0.009
August	1.64	0.041	-2.37	-0.042*	0.54	0.006	0.52	0.000
September	1.85	0.104+	-0.20	-0.004	0.22	0.000	0.25	0.000

Month	Simikot		Dipalgaun		Khudibazzar		Jiri	
	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope
October	1.26	0.129	1.39	0.043	0.94	0.027	1.68	0.050^{+}
November	1.34	0.143	-1.03	-0.021	0.79	0.025	2.34	0.060*
December	-0.05	-0.025	0.75	0.020	2.32	0.047*	1.25	0.027
Annual average	1.79	0.314^{+}	-0.36	-0.008	0.91	0.013	2.38	0.031*

*$^{+}$α, 0.1 level of significance; *α, 0.05 level of significance; **α, 0.01 level of significance; ***α, 0.001 level of significance.*

Table 4. Mann-Kendall trend test and Sen's slope estimate of monthly and annual rainfall atSimikot, Dipalgaun, Khudibazzar and Jiri during 1978-2017

Month	Simikot		Dipalgaun		Khudibazzar		Jiri	
	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope
January	1.78	0.920^{+}	0.75	0.410	-0.76	-0.023	-0.64	-0.200
February	1.23	1.222	-1.13	-0.688	-1.86	-1.076^{+}	-0.73	-0.243
March	-0.42	-0.560	-0.71	-0.396	0.21	0.201	-0.32	-0.228
April	-1.14	-0.530	-0.10	-0.103	1.57	2.133	1.01	1.486
May	-0.93	-0.972	0.00	-0.020	-0.36	-0.783	-0.68	-1.461
June	1.26	1.696	-0.18	-0.444	-1.68	-5.692^{+}	-0.29	-1.019
July	-1.03	-1.677	-0.28	-0.593	0.57	4.126	1.53	4.550
August	0.00	0.175	-1.07	-1.928	-2.96	-9.756**	-0.22	-1.103
September	-0.88	-1.080	-1.39	-1.550	-0.24	-0.875	1.41	2.864
October	0.30	0.000	0.50	0.040	1.86	2.312^{+}	1.96	1.575*
November	0.92	0.000	-1.11	0.000	-1.66	-0.098^{+}	-2.16	-0.361*
December	-1.32	-0.182	-1.57	0.000	-3.14	-0.142**	-1.42	-0.041
Annual total rainfall	-0.28	-3.467	-1.17	-4.252	-1.17	-12.370	1.00	8.847

*$^{+}$α, 0.1 level of significance; *α, 0.05 level of significance; **α, 0.01 level of significance; ***α, 0.001 level of significance.*

Table 5. Mann-Kendall trend test and Sen's slope estimate of monthly and annual average relative humidity (%) at Simikot, Dipalgaun, Khudibazzar and Jiri during 1978-2017

Month	Simikot		Dipalgaun		Khudibazzar		Jiri	
	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope	Z	Sen's slope
January	1.65	0.612^{+}	2.38	0.629*	-0.05	-0.010	0.96	0.056
February	0.36	0.169	1.94	0.319^{+}	0.29	0.015	-0.73	-0.044
March	0.00	0.033	1.43	0.230	-0.07	-0.014	1.37	0.129
April	-0.11	-0.050	1.22	0.240	1.36	0.317	1.74	0.252^{+}
May	1.86	0.643^{+}	2.36	0.361*	0.46	0.095	1.46	0.129
June	0.88	0.323	0.40	0.072	-0.09	-0.012	1.67	0.102^{+}
July	1.65	0.540^{+}	-2.17	-0.250*	2.19	0.119*	3.08	0.096**
August	1.37	0.200	-3.44	-0.375***	1.12	0.058	3.66	0.165***
September	1.02	0.271	-1.34	-0.131	1.22	0.067	3.40	0.163***
October	1.68	0.890^{+}	1.52	0.250	0.77	0.068	3.38	0.200***
November	1.59	0.721	0.99	0.293	1.75	0.170^{+}	0.42	0.021
December	1.49	0.968	2.73	0.451**	1.15	0.100	0.39	0.015
Annual average	1.30	0.619	2.26	0.274*	1.25	0.099	3.04	0.094**

*$^{+}$α, 0.1 level of significance; *α, 0.05 level of significance; **α, 0.01 level of significance; ***α, 0.001 level of significance.*

Table 6. Severity of diseases of selected crops at Chhipra (Humla), Hanku (Jumla), Ghanpokhara (Lamjung) and Jugu (Dolakha) during 2015-2018

Crop name	Pathogen	Diseases name	Severity			
			Humla (Chhipra)	Jumla (Hanku)	Lamjung (Ghanpokhara)	Dolakha (Jughu)
Amaranth	*Colletotrichum gloeosporioides*	Anthracnose		L (2016)		
Amaranth	*Cercospora canescens*	Cercospora leaf spot		L (2016)		
Naked barley	*Helminthosporium gramineum*	Barley stripe			M (2016)	
Naked barley	*Blumeria graminis* f. sp. *hordei*	Powdery mildew			M-H (2016)	

Crop name	Pathogen	Diseases name	Severity			
			Humla (Chhipra)	Jumla (Hanku)	Lamjung (Ghanpokhara)	Dolakha (Jughu)
Naked barley	*Bipolaris sorokiniana*	Spot blotch			L (2016)	
Naked barley	*Ustilago hordei*	Covered smut			VL (2016)	
Beans	*Colletotrichum lindemuthianum*	Anthracnose	L/M(2018)	L/M (2016)	L (2015)	L (2015) M (2017)
Beans	*Isariopsis griseola*	Angular leaf spot	M/H (2018)	H-M (2016)	L-M (2015)	M (2017)
Beans	*Uromyces appendiculatus*	Rust		L-M (2016)	M-H (2015)	
Beans	*Sclerotinia sclerotiorum*	White mold		H-M (2016)		
Beans	*Bean Yellow Mosaic Virus* (BYMV)	Bean yellow mosaic				L-M (2015)
Beans	*Bean Common Mosaic Virus (BCMV)*	Bean common mosaic		L-M (2016)	L-M (2015)	
Buckwehat	*Erysiphe polygoni*	Powdery mildew				VL (2015)
Fingermillet	*Pyricularia grisea*	Blast		L-M (2016)	Low (2016)	L-M (2015)
Fingermillet	*Cercospora eleusine*	Cercospora leaf spot			M-H (2015)	L (2015)
Foxtail millet	*Pyricularia setariae*	Blast		M (2016)	VL (2015)	
Foxtail millet	*Bipolari* ssp.	Blight		L-M (2016)		
Prosomillet	*Pyricularia grisea*	Blast	L (2017)	L (2016)		L (2015)
Prosomillet	*Sphacelotheca destruens*	Head smut	L (2017)			
Rice	*Pyricularia oryzae*	Blast		H (2016)	M-H (2015)	M-H (2015)

VL, very low; L, low severity; M, medium severity, H, high severity; Disease recorded years are given in parentheses.

DISCUSSION

Selvaraju et al (2014) stated that the climate of Nepal varies greatly in both time and space. Increasing trend of temperature in the study location is the evident of climate change over the Nepal.Warming is more pronounced in the high-altitude regions than in the Tarai (Selvaraju et al 2014). Climate change is also likely to change the monsoon pattern of Nepal. After analyzing the data from Simikot, Jumla, Lamjung and Dolakha this study found that there is changing trend in the climatic variable over the years.The impacts of climate change can be positive, negative or neutral, since these changes can decrease, increase or have no impact on plant diseases, depending on each region or period (Raquel et al 2008). Due to their large populations, the ease with which they multiply and become disseminated, and their short generation times, pathogens will likely be among the first organisms to exhibit the effect of climate change (Scherm et al 2000). Changes in temperature and precipitation regimes due to climate change may alter the growth stage, development rate and pathogenicity of infectious agents (Chakraborty and Datta 2003) and modify physiology and resistance of the host plant (Gautam et al 2013).

A change in temperature could directly affect the spread of infectious diseases and their survival between seasons (Gautam et al 2013) by favoring the development of different dormant pathogens, which could induce an epidemic (Mcelrone et al 2005). In many cases, temperature increases are predicted to lead to the geographic expansion of pathogen and vector distributions, bringing pathogens into contact with more potential hosts and providing new opportunities for pathogen hybridization (Baker et al 2000, Brasier 2001, Brasier et al 1999). Moreover, host resistance to disease may be overcome quickly by more rapid disease cycles, resulting in a greater chance of pathogens evolving to overcome host-plant resistance (Gautam et al 2013).

Effect of climate change on blast diseases

Blast diseases are the major problems in rice, fingermillet, foxtailmillet and prosomillet at the study sites but pathogen species are different (**Table** 6).Climatic factors for these crops from April to October are very important (**Appendix** 1-4) and also for the diseases as climatic factors are important for the development of blast diseases.Kang and Dobinson (2004) stated that the broad collective host range of blast fungi puts at risk numerous members of the grass family. For the disease cycle of blast, from the germination of spores to the development of lesions, the most important climatic factors are temperature and precipitation or the deposition of dew (Bevitori and Ghini 2014).In all the present study sites, the range of temperatures (**Figure** 2-5) during the crop (rice, finger millet, foxtail millet and prosomillet) growing seasons are favorable for the development of blast diseases. Luo et al (1995) used models to study the effects of temperature and UV-B on rice blast disease and predicted an increase in rice blast severity in several zones of Asia; which showed that changes in precipitation did not affect epidemics and had little effect on the leaf wetness period in their model. However, in cold subtropical areas, an increase in temperature was found to cause an increase in the severity of disease and in the area under the disease progress curve. These results may be attributable to an increased risk of infection at elevated temperatures, especially under the conditions of the present study sites. Ghini et al (2008) also stated that in cool subtropical zones, higher temperatures caused increases in disease severity and in the area bellow the disease progress curve, because higher risk of epidemics occurs under higher temperatures.

Effect of climate change on other diseases

Climate change may also influence whether pathogen populations reproduce sexually or asexually; in some cases, altered temperatures may favor overwintering of sexual propagules, thus increasing the evolutionary potential of a population (Pfender and Vollmer 1999). In case of biotrophic fungi, an increase in disease severity has been found for six of ten fungi studied and a decrease for the other four. Similarly, in case of 15 necrotrophic fungi studied, nine exhibited an increase in disease severity, four exhibited a decrease, and two remained unchanged (Chakraborty et al 1998). Pathogens such as *Sclerotinia sclerotiorum*, which causes stem or white rot in a wide range of vegetable crops, are likely to release spores in synchrony with earlier flowering of crops (Sharma et al 2010). Excess moisture, on the other hand, favors some dreaded soil-borne diseases caused by *Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani* and *Sclerotium rolfsii*, especially in pulses (Sharma et al 2010). Other pathogens like the powdery mildew species tend to thrive under conditions with lower (but not low) moisture (Coakley et al 1999). Some pathogens also develop new races that can adopt on changing climate and have more aggressive than previous races. In the USA, recent epidemics of wheat stripe rust (yellow rust; *P. striiformis* f. sp. *tritici*) appear to have resulted from an increase in prevalence of strains adapted to warmer temperatures and the strains were found capable of overcoming the long-standing resistance genes Yr8 and Yr9 (Garrett et al 2009).

Changing trends of temperature can change the diseases equilibrium in the specific region/location, reduces the importance of major diseases or increase the importance of minor diseases on the same crops over the period of time. Kaur et al (2008) suggested that in wheat belt of Punjab, India, the importance of yellow rust (*P. striiformis*) and Karnal bunt (*Tilletia indica*) will be reduced with increasing temperature and humidity; while the importance of leaf rust, foliar blights, Fusarium head blight and stem rust may increase in the future, particularly in the absence of resistance in wheat cultivars. Coakley et al (1999) suggested that in the presence of susceptible hosts, pathogens with short life cycles, high reproduction rates and effective dispersion mechanisms respond quickly to climate change, resulting in faster adaptation to climatic conditions. Similarly, the incidence of vector-borne virusand other diseases will be altered as climate change can substantially influence the development and distribution of vectors (Gautam et al 2013).In case of insect-vectored diseases if warmer temperatures translate into additional insect generations (as they often do) obviously this will increase transmission rate of the invasive pathogen (Dobson 2009).

CONCLUSIONS

This study concludes that temperature is increasing over the year but that increases varied from place to place, whereas rainfall did not follow the same trends at all the locations. The results of this research can be used by organizations and researchers to assess the current climate variability and fluctuations and disease situations on traditional crops in the mountains of Nepal. The main shortcoming of this study is the generalization of climatic data of the nearest meteorological stations to the study sites that exclude the micro climatic variations. Time series data on local crops diseases were not available. Therefore, investigations on plant disease incidence over time, especially of traditional mountain crops, in relation with climate change are highly recommended. A further study might be justifiable to validate this technical study by assessing farmers' perception on the changes in disease incidence and severity in relation with farmers' perception on the trend of changes in climatic parameters.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the project field staff for conducting the trial and Department of Hydrology and Meteorology (DHM), Nepal for accessing the climatic data of the study site.

REFERENCES

Baker RHA, CE Sansford, CH Jarvis, RJC Cannon, A MacLeod, and MFA Walters. 2000. The role of climatic mapping in predicting the potential geographical distribution of non-indigenous pests under current and future climates. Agriculture, Ecosystems & Environment **82**:57-71.

Bevitori R and R Ghini. 2014. Rice blast disease in climate change times. Journal of Rice Research **3**:111-116.

Bhuyan MDI, MM Islam and MEK Bhuiyan. 2018. A trend analysis of temperature and rainfall to predict climate change for northwestern region of Bangladesh. American Journal of Climate Change **7**:115-134.

Brasier CM, DEL Cooke and JM Duncan. 1999. Origin of a new *Phytophthora* pathogen through interspecific hybridization. Proceedings of the National Academy of Sciences of the United States of America **96**:5878-5883.

Brasier CM. 2001. Rapid evolution of introduced plant pathogens via interspecific hybridization. Biological Science **51**:123-133.

CBS. 2013. Statistical Information on Nepalese Agriculture; Central Bureau of Statistics (CBS): Kathmandu, Nepal. 2013.

Chakraborty S and S Datta. 2003. How will plant pathogens adapt to host plant resistance at elevated CO2 under a changing climate? New Phytologist **159**:733-742.

Chakraborty S., AV Tiedemann and PS Teng. 2000. Climate change: potential impact on plant diseases. Environmental Pollution **108**:317-326.

Chakraborty S, GM Murray, PA Magarey, T Yonow, RG O'Brien, BJ Croft, MJ Barbetti, K Sivasithamparam, KM Old, MJ Dudzinski, RW Sutherst, LJ Penrose, C Archer and RW Emmett. 1998. Potential impact of climate change on plant diseases of economic significance to Australia. Australisian Plant Pathology **27**:15-35.

Coakley SM, H Scherm, and S Chakraborty. 1999. Climate change and plant disease. Annual Review of Phytopathol.**37**:399-426.

DHM. 2017. Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971-2014). Department of Hydrology and Meteorology, Kathmandu.

DHM. 2015. Study of Climate and Climatic Variation over Nepal. Department of Hydrology and Meteorology, Ministry of Population and Environment, Nepal.

Dobson A. 2009. Climate variability, global change, immunity, and the dynamics of infectious diseases. Ecology **90**:920-927.

Garrett KA, M Nita, ED Dewolf, L Gomez and AH Sparks. 2009. Plant pathogens as indicators of climate change. **In**: Climate and Global Change: Observed Impacts on Planet Earth (ed Letcher, TM), Elsevier, Oxford; **pp**.425-437.

Gautam HR, ML Bhardwaj and R Kumar. 2013. Climate change and its impact on plant diseases. Current science **105**(12):1685-1691.

Ghini R, E Hamada and W Bettoil. 2008. Climate change and plant diseases. Scientia Agricola **65**:98-107.

Gumma MK, D Gauchan, A Nelson, S Pandey and A Rala. 2013. Temporal changes in rice growing area and their impact on livelihood over a decade: A case study of Nepal. Agric. Ecosyst. Environment **142**:382-392.

Gurung R, SR Sthapit, D Gauchan, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: II. Ghanpokhara, Lamjung. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD/NARC /Bioversity International Nepal.

HMGN/MFSC. 2002. Nepal Biodiversity Strategy. His Majesty's Government of Nepal Ministry of Forest and Soil Conservation, Nepal.

IPCC. 2007. Climate Change, the Fourth IPCC Assessment Report, Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.

Joshi BK, N Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020. Agrobiodiversity and its Conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33

Kang S and KF Dobinson. 2004. Molecular and genetic basis of plant fungal pathogen interaction. Applied Mycology and Biotechnology **4**:59-97.

Karpouzos D, S Kavalieratou and C Babajimopoulos. 2010. Trend analysis of precipitation data in Pieria region (Greece). European Water **30**:31-40.

Kaur S, L Dhaliwal and P Kaur. 2008. Impact of climate change on wheat disease scenario in Punjab. Journal of Research **45**(3 and 4):161-170.

Lama S and B Devkota. 2009. Vulnerability of mountain communities to climate change and adapation strategies. The Journal of Agriculture and Environment, **10**:65-71.

Logan JA, J Régnière and JA Powell. 2003. Assessing the impacts of global warming on forest pest dynamics. Frontiers in Ecology and the Environment **1**:130-137.

Lonsdale D and JN Gibbs. 1996. Effects of climate change on fungal diseases of trees. **In**: JC Frankland, N Magana and GM Gadd (Eds.). Fungi and Environmental Change, Cambridge University Press, Cambridge; **p**. 1019.

Luo Y, DO Tebeest, PS Teng and NG Fabellar. 1995. Simulation studies on risk analysis of rice leaf blast epidemics associated with global climate change in several Asian countries. Journal of Biogeography **22**:673-678.

Malla G. 2008. Climate change and its impact on Nepalese agriculture. The journal of Agriculture and Environment **9**:62-71.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhey, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis, and BR Sthapit. 2016. A Field Guide for Identification and Scoring Methods of Diseases in the Mountain Crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

Mcelrone AJ, CD Reid, KA Hoye, E Hart and RB Jackson. 2005. Elevated CO2 reduces disease incidence and severity of a red maple fungal pathogen via changes in host physiology and leaf chemistry. Global Change Biology **11**:1828-1836.
MoF. 2017/18. Economic Survey.Government of Nepal, Ministry of Finance, Singh Durbar, Kathmandu.
NCVST. 2009. Vulnerability through the Eyes of Vulnerable: Climate Change Induced Uncertainties and Nepal's Development Predicaments, Institute for Social and Environmental Transition Nepal (ISET-N), Nepal climate vulnerability study team (NCVST) Kathmandu.
Palikhey E, SR Sthapit, S Gautam, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report III. Hanku, Jumla. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.
Parajuli A, A Subedi, AR Adhikari, SR Sthapit, BK Joshi, D Gauchan, B Bhandari and BR Sthapit. 2016. Baseline Survey Report: IV. Chhipra, Humla. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.
Pfender WF and SS Vollmer. 1999. Freezing temperature effect on survival of *Puccinia graminis* sub sp. *graminicola* in *Festuca arundinacea* and *Lolium perenne*. Plant Disease**83**:1058-1062.
Poudel S and K Kotani. 2013. Climatic impacts on crop yield and its variability in Nepal: do they vary across seasons and altitudes? Climatic Change **116**:327-355.
Poudel S and R Shaw. 2016. The relationships between climate variability and crop yield in a mountainous environment: A case study in Lamjung district, Nepal. Climate **4**(13):2-13.
Practical Action 2007. Promoting Adaptation to Climate Change in Nepal: A Briefing for Government Advisors and Development Practitioners. Practical Action, Kathmandu Office, Nepal.
Practical Action. 2009. Temporal and Spatial Variability of Climate Change Over Nepal (1976-2005). Practical Action, Kathmandu Office, Nepal.
Pudasaini N, SR Sthapit, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: I. Jungu, Dolakha. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. Li-BIRD/ NARC/ Bioversity International, Pokhara, Nepal.
Raquel G, E Hamada and W Bettiol. 2008. Climate change and plant diseases. Scientia Agricola **65**:98-107.
Salmi T, A Maatta, P Anttila, T Ruoho-Airola and T Amnell. 2002. Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen'sSlope Estimates-The Excel Template Application Makesens. Finnish Meteorological Institute Publications on Air Quality No. 31, Helsinki.
Scherm H, RW Sutherst, R Harrington and JSI Ingram. 2000. Global networking for assessment of impacts of global change on plant pests. Environ Pollution **108**:333-341.
Selvaraju R, KR Regmi, DB Singh, R Singh, JL Nayava, U Simkhada, C Adhikari, B Gautam, R Dhakal, N Pandey, B Pokharel, A Deo and N Rana. 2014. Managing Climate Risks and Adapting to Climate Change in the Agriculture Sector in Nepal. Food and Agriculture Organization of the United Nations Rome.
Sharma M, UN Mangala, M Krishnamurthy, V Vadez and S Pande. 2010. Drought and dry root of chickpea. **In**: Proceedings of the 5th International Food Legumes Research Conference (IFLRC V) and 7th European Conference on Grain Legumes (AEP VII), Antalya, Turkey.
Shrestha A, CP Wake, PA Mayewski and JE Dibb. 1999. Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971–94. Journal of Climate **12**(9):2775–2786.
Sweeney C, M New and G Lizcano. 2008. UNDP climate change country profiles: Nepal. http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Nepal/Nepal.lowres.report.pdf.

Appendix 1. Crop calendar showing seed to intercultural operations and harvesting of different local crop at Chhipra, Humla

Nepali calender	Baisakh				Jestha				Ashad				Shrawan				Bhadra				Asoj				Kartik				Mangsir				Falgun				Chaitra			
English calender	Apr-May				May-Jun				Jun-Jul				Jul-Aug				Aug-Sep				Sep-Oct				Oct-Nov				Nov-Dec				Feb-Mar				Mar-Apr			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Amaranth	S	S									IN	IN	IN									H	H	H															P	P
Barley/Naked barley					H	H	H																			P	P	S	S								IN	IN		
Beans	S	S								IN	IN	IN	IN								H	H	H	H													P	P	S	S
Buckwheat					P	P	S	S	S	S		IN	IN	IN									H	H	H															
Finger millet				P	P	T	T	T	T			IN	IN	IN									H	H	H													P	N	N
Foxtail millet	S	S										IN	IN	IN									H	H	H											P	P	P	S	S
Proso millet		P	P	S	S	S			IN	IN	IN	IN								H	H	H																		
Rice					P	P	T	T					IN	IN	IN	IN							H	H	H											P	SK	N	N	N

SK, soaking of rice seed; N, setting of nursery bed; S, sowing of seed; T, transplanting of seedlings; H, harvesting; IN, intercultural operation; P, plouging the fields (Parajuli et al 2016).

Appendix 2. Crop calendar showing seed to intercultural operations and harvesting of different local crop at Hanku, Jumla

Nepali calendar	Baisakh				Jestha				Ashad				Asoj				Kartik				Mangsir				Chaitra			
English calendar	Apr-May				May-Jun				Jun-Jul				Sep-Oct				Oct-Nov				Nov-Dec				Mar-Apr			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Amaranth	S	S												H	H	H												
Barley/Naked barley					H	H	H													S	S	S						
Beans							S	S	S	S			H	H	H													
Buckwheat							S	S	S	S			H	H	H													
Finger millet						T	T	T	T				H	H	H												N	N
Foxtail millet	S	S											H	H	H													S
Proso millet	S	S											H	H	H													S
Rice								T	T					H	H	H	H									SK	N	N

SK, soaking of rice seed; N, setting of nursery bed; S, sowing of seed; T, transplanting of seedlings; H, harvesting; IN, intercultural operation; P, plouging the fields (Palikhe et al 2016).

Appendix 3: Crop calendar showing seed to intercultural operations and harvesting of different local crop at Jungu, Dolakha

Nepali calendar		Baisakh				Jestha				Ashad				Shrawan				Bhadra				Asoj				Kartik				Mangsir				Magh				Falgun				Chaitra			
English calendar		Apr-May				May-Jun				Jun-Jul				Jul-Aug				Aug-Sep				Sep-Oct				Oct-Nov				Nov-Dec				Jan-Feb				Feb-Mar				Mar-Apr			
Weeks	Ele	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Amaranth	<1500	S	S																									H	H	H	H													S	S
Barley/Naked barley	<1500	H	H																	S	S	S																						H	H
Barley/Naked barley	>1500					H	H	H	H												S	S																							
Beans	>1500	S	S							H	H	H	H																															S	S

Nepali calendar		Baisakh				Jestha				Ashad				Shrawan				Bhadra				Asoj				Kartik				Mangsir				Magh				Falgun				Chaitra			
Beans (Chaumase)	<1500			H	H	H	H	H	H						S	S	S	S						H	H	H	H	H	H	H							S	S	S						
Beans (Local)	<1500	S	S							H	H	H	H																															S	S
Buckwheat	>1500																	S	S	S	S				H	H	HH																		
Buckwheat (Khet)	<1500							H	H	H	H	H	H																												S	S	S	S	S
Finger millet	<1500				N	√	N	N	N	N	T	T	T	T	T	T									H	H	H	H	H	H															
Finger millet	>1500	N	N	N	N	N			T	T	T	T	T													H	H	H	H	H															
Rice	<1500					N	N	N	N	T	T	T	T	T													H	H	H	H	H														
Rice	>1500	N					T	T	T	T																H	H	H	H																N

SK, soaking of rice seed; N, setting of nursery bed; S, sowing of seed; T, transplanting of seedlings; H, harvesting; IN, intercultural operation; P, plouging the fields (Pudasaini et al 2016).

Appendix 4: Crop calendar showing seed to intercultural operations and harvesting of different local crop at Ghanpokhara, Lamjung

Nepali calendar		Baisakh				Jestha				Ashad				Shrawan				Bhadra				Asoj				Kartik				Mangsir				Poush				Magh				Falgun				Chaitra			
English calendar		Apr-May				May-Jun				Jun-Jul				Jul-Aug				Aug-Sep				Sep-Oct				Oct-Nov				Nov-Dec				Dec-Jan				Jan-Feb				Feb-Mar				Mar-Apr			
Weeks	Ele	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Amaranth	All	S	S	S	S																	S	S	S	S																								
Barley/Naked barley	All	H	H																										S	S	S																	H	H
Beans	All	S	S												H	H	H	H																															
Fingermillet	<1400					√	N	N						T	T	T				IN	IN	IN	IN					H	H	H	H																		
Fingermillet	>1400		N	N	N					T	T	T	T				IN	IN	IN	IN							H	H	H	H																			
Fingermillet (Barkhe)	<1000	IN	IN	IN					H	H	H																																	S	S	S	S		
Foxtail millet	<1300	IN	IN						H	H	H	H	H																															S	S	S	S		
Rice	All		N	N	N					T	T	T	T	T	T		IN	IN	IN	IN	IN					H	H	H	H									P	P	P	P	P	P	P					

SK, soaking of rice seed; N, setting of nursery bed; S, sowing of seed; T, transplanting of seedlings; H, harvesting; IN, intercultural operation; P, ploughing the fields (Gurung et al 2016).

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Finger Millet Germplasm Evaluation for Blast Disease Resistance and Agronomical Traits in Dolakha, Nepal

Suk Bahadur Gurung, Bal Krishna Joshi and Ram Chandrika Prasad

ABSTRACT

This experiment was conducted to identify blast disease resistant and better agronomic traits containing finger millet germplasm. Altogether 156 finger millet genotypes were evaluated in a field experiment at Hill Crops Research Program (HCRP), Kabre, Dolakha, Nepal. Seed sowing was done in June and crop was harvested during October 2015. This experiment consisted of standard and susceptible checks at each 11th and 12th entries in a rod-row design with the plot size 0.5 m^2 in crop geometry of line to line 25 cm and plant to plant 10 cm. Trial plot was surrounded by two rows of blast susceptible mixture of finger millet for the production of sufficient inoculums to infect the test genotypes under natural conditions. Most of the test entries were found under moderately resistant category for leaf, neck and finger blasts. Not all the resistant genotypes gave higher grain yield. Some genotypes like ACC#2424 (4.02 t/ha), ACC#522 (4.01 t/ha), ACC#519 (3.82 t/ha), ACC#2289, (3.76 t/ha) ACC#2723 (3.61 t/ha) and ACC#530 (3.23 t/ha) were found superior in blast resistance as well as in terms of grain yield. Other moderately susceptible but high yielding genotypes can be used in hybridization program to develop new varieties for the purpose of general cultivation under divergent climatic conditions. Genotypes having higher yield capacity but susceptible to blast disease like ACC#2408 (4.06 t/ha), ACC#2608 (3.95 t/ha), ACC#2707 (3.95 t/ha), ACC#2620 (3.93 t/ha) and ACC#460 (3.90 t/ha) can be used for mixed cultivation with resistant genotypes based on their suitability in other agronomic traits.

Keywords: Blast, finger millet, field experiment, germplasm, resistance, yield

INTRODUCTION

Finger millet (*Eleusine coracana* G.) is the fourth cereal crop in terms of area and production in Nepal after rice, maize and wheat. It is a cheap and economical source of food to the poor people dwelling in inaccessible hilly regions of the country (Upreti 1993). It is rich in calcium (Ca), iron (Fe) and nutritionally superior to other food crops in terms of energy, proteins, vitamins and other minerals (Joshi et al 2020a). Its consumption is considered highly advantageous for the people suffering from diabetes by delayed nutrient absorption and heart patient as it also lowers blood lipids (Tharanathan and Mahadevamma 2003). Finger millet is mainly consumed in the form of thick and thin porridge and bread but a significant part of its production is utilized for local beverage production in rural Nepal (Adhikari 2012). The fodder is best suited during the lean season in mountain region and the malted grain is used as food for infants. Though traditional assumptions considered it as a low status food in the society but growing awareness about its nutritional value has increased its demand day by day.

In Nepal, finger millet occupied 263,596 ha of land which was about 7.7% of total cereal cultivated area and produced 306,704 tons with the productivity 1,160 kg/ha (MoAD 2017). The crop is relayed with maize under mid-hills environment of eastern, central and western part of the country whereas under mono condition in mid and far western region (Prasad 2008). Finger millet grain is practically safe from storage pests and has very long postharvest storage life as compared to other crops.

So far, only five varieties have been released on finger millet (Kabre Kodo-1, Kabre Kodo-2, Okhle-1, Dalle-1 and Sailung Kodo-1) (Joshi et al 2017). Though these varieties are still showing good performance which may not continue in coming years due to various biotic and abiotic constraints. Moreover, lack of varietal options for finger millet growing farmers in different agro-ecological belts demands new varieties on this crop. Mixing of different genotypes having similar agronomic traits will be another good option to suppress the disease pressure and conserve the finger millet diversity (Joshi et al 2020b).

Finger millet gets affected by several diseases such as blast, foot rot, smut, streak and mottling viruses (Patro and Madhuri 2014). These diseases cause losses not only to quantity but also the quality and affect market value of the crop. Among different diseases, blast (*Pyricularia grisea*) and Cercospora leaf spot (*Cercospora eleusine*) are major diseases in Nepal. These diseases deteriorate grain quality leading to reduction in flour recovery; likewise, straw quality is also mangled owing to infection of Cercospora disease. Blast whenever infects finger millet can cause larger grain yield loss than other diseases. Mc Rae (1922) who first time reported yield loss estimation by blast in finger millet found more than 50%. Different yield loss reports showed significant loss by blast disease (Ramappa et al 2002, Vishwanath et al 1986). Batsa and Tamang (1983) found yield reduction up to 100% under favorable conditions in Rampur, Chitwan, Nepal. Blast fungus in finger millet can be managed chemically (HCRP 2007) but poses environmental threat if used indiscriminately (Karthikeyan et al 2000). Thus, use of disease resistant sources is an ultimate need.

The blast fungus produces lesions on most of the aerial portion of the plant. Typically, elliptical leaf spot with gray or whitish center with reddish brown margin is seen in leaf, neck and fingers. Whenever the environment becomes favorable the spots may coalesce and complete drying of aerial portion may occur. It ultimately reduces the grain weight, grain number with sterile fingers leading significant yield loss. Disease causing pathogens are dynamic in nature and modify themselves according to the selection pressure in them. The reasons behind this might be pre-existing variations or novel variations in the pathogen population (Sridhar and Singh 2001).

The experiment was designed and conducted at Hill Crops Research Program (HCRP), Kabre to assess the response of finger millet germplasm to blast disease. The HCRP domain has good environment and aggressive blast pathogen suitable for varietal screening for finger millet (Khadka et al 2013). The experiment was also aimed in amalgamating the superior genotypes in their yield attributing traits, pathological behaviors as well as their phenotypic characters and finding compatible cultivar mixture.

MATERIALS AND METHODS

Altogether 156 germplasm of finger millet including standard check (Kabre Kodo-1) and susceptible check (ACC#2303) for blast at each 11th and 12th entries were tested at HCRP, Kabre, Dolakha in summer of 2015. The experiment was conducted in augmented design with plot size of 1 meter long and two rows at spacing of line to line 25 cm and plant to plant continuous during sowing but maintained 10 cm after thinning. Ten numbers of hills were maintained in each row by thinning after 45 days of sowing. Chemical fertilizer was applied at the rate of 60:30:20 NPK kg/ha of which half dose of nitrogen and full dose of phosphorus and potash were applied as basal dose while remaining nitrogen was top dressed during active tillering phase. The field plot was surrounded by two rows of susceptible mixture composed of Dolakha local finger millet and susceptible check ACC#2303 to produce sufficient blast inoculums. Border lines were not thinned to favor sporulation and dissemination of airborne conidia of blast pathogen. Other standard agronomical practices were followed.

Grain yield and yield attributing characters were measured. Leaf blast was recorded 3 times on 0-9 scale during vegetative phase while neck and finger blast were recoded once on the basis of percentage during dough stage of the crop and converted into 0-9 scale. In which '0' indicated disease free, '1' resistant, '2-3' moderately resistant, '4-5' moderately susceptible, '6-7' susceptible and '8-9' highly susceptible. Leaf blast, neck blast and finger blast were recorded as follows:

Leaf blast rating scale (0-9) modification of Kiran Babu et al (2013)

Scale		Description
0	=	no spots
1	=	small brown specks
2	=	large brown spot (1-2 mm diameter) on lower leaves
3	=	large brown spot (1-2 mm diameter) on upper leaves
4	=	typical susceptible blast lesion (3 mm or longer) covering upto 2% leaf area
5	=	typical blast lesion covering 3-10% of leaf area
6	=	typical blast lesion covering 11-25% of leaf area
7	=	typical blast lesion covering 26-50% of leaf area
8	=	typical blast lesion covering 51-75% of leaf area
9	=	leaf spots covering >75% of leaf area

Neck blast (NB)

Percent disease incidence (PDI-NB)= $\frac{\textbf{Numbers of Infected neck*100}}{\textbf{Total numbers of ear head observed}}$

Finger blast (FB)

Percent disease incidence (PDI-FB) = $\frac{Numbers\ of\ Infected\ fingers\ per\ plant * 100}{Numbers\ of\ finger\ per\ plant}$

Conversion of percent disease incidence (PDI) of neck and finger blast in 0-9 scale (Modification of Nagaraja et al 2007)

Percent disease incidence range	Score	Reaction
0	0	Disease free
1-5	1	Resistant
5-10	2	Moderately resistant
10-20	3	
20-30	4	Moderately susceptible
30-40	5	
40-50	6	Susceptible
50-70	7	
70-85	8	Highly Susceptible
85-100	9	

Data analysis

Agronomic data were averaged and analyzed using MS-Excel. Area under the disease progress curve (AUDPC) was calculated for leaf blast for all germplasm according to the following formula (Shaner and Finney 1977).

$$\text{A.U.D.P.C.} = \sum_{i}^{n-1}\left[\left\{\frac{Yi + Y(i+1)}{2}\right\} x(t(i+1) - ti)\right]$$

In which *Yi* = disease severity on the *i*th date; *ti*= *i*th day; *n* = number of dates on which blast disease was recorded. Whereas percent of disease incidence were calculated for neck and finger blast for each accession using the formulae mentioned above.

RESULTS

Responses of finger millet germplasm to blast disease

Wider ranges of variations were observed among finger millet accessions for leaf blast, neck blast and finger blast responses. All the germplasms were found infected by leaf and neck blast but few were free to finger blast. Most of the genotypes were found moderately resistant to blast disease. Almost half of the evaluated germplasm showed moderately susceptible reaction to leaf blast but none of them was highly susceptible to any of the blast disease (leaf, neck and finger blast) (Table 1).

Table 1. Number of finger millet germplasm in different category of blast disease response evaluated at HCRP, 2015

Response of finger millet germplasm to blast	Number of finger millet germplasm under different blast disease responses		
	Neck blast	Finger blast	Leaf blast
Disease free (DF)	0	4	0
Resistant (R)	5	10	1
Moderately resistant (MR)	117	105	90
Moderately susceptible (MS)	29	27	63
Susceptible (S)	1	4	0
Highly susceptible (HS)	0	0	0

Blast disease and yield

High yielding germplasm showed differential reactions to blast disease. However, of the 156, 77 germplasm produced higher yield when compared with the overall average yield (2.52 t/ha). Forty-six germplasm yielded more than standard check Kabre kodo-1 (2.92 t/ha). Some of the genotypes ACC#2408 (4.1 t/ha), ACC#459 (3.97 t/ha), ACC#2608 (3.95 t/ha), ACC#2707 (3.95 t/ha) being moderately susceptible to blast disease also yielded higher than standard check (Table 2).

Not all the germplasm resistant to leaf, neck and finger blast produced higher yield rather some of them produced yield below average (2.52 t/ha). Average value for leaf blast AUDPC was 64 and 16 for both neck and finger blast. ACC#519 showed resistant to both neck and finger blast with yield potentiality of 3.82 t/ha (Table 3). Germplasm yielding more than 4 t/ha were found to be moderately resistant to blast disease. Some of the germplasm had performed better than the national check in yield attributing traits and blast resistance.

Table 2. Superior finger millet germplasm in terms of yield with their disease response at HCRP, summer 2015

Genotypes	Plant height (cm)	DTH	DTM	Bearing head/m2	No. of fingers /head	AUDPC (LB)	PDI (NB)	PDI (FB)	Grain yield (t/ha)
ACC#2408	89	81	137	166	10	60	12	16	4.06
ACC#2424	102	81	143	142	9	85	10	6	4.02
ACC#522	88	95	145	130	9	60	8	4	4.01
ACC#511	90	80	132	130	10	65	8	9	3.99
ACC#459	80	79	132	142	9	40	7	10	3.97
ACC#2608	85	75	133	178	9	105	9	19	3.95
ACC#2707	65	76	143	132	9	50	7	13	3.95
ACC#2620	92	79	132	140	8	60	19	8	3.93
ACC#460	86	81	134	176	7	65	6	23	3.90
ACC#2358	96	81	137	90	6	50	16	8	3.83
ACC#2303 (Susceptible Check)	80	80	135	85	8	72	14	18	2.47
Kabre Kodo 1 (Resistant Check)	87	85	135	89	7	61	15	16	2.92
Average (of total)	84	79	136	114	8	64	16	16	2.52
Maximum (of total)	105	95	145	234	88	125	67	68	4.06
Minimum (of total)	39	64	125	48	4	20	4	0	0.76
Standard dev. (of total)	10	7	4	32	7	16	9.67	12.40	0.77
Skewness	-0.71	0.09	0.63	0.68	-0.01	0.51	1.93	1.86	0.023

DTH, days to heading; DTM, days to maturity; AUDPC, area under disease progress curve; PDI, percent disease incidence; LB, leaf blast; NB, neck blast; FB, finger blast; t/ha, ton per hectare.

Table 3. Blast disease resistant finger millet germplasm evaluated at HCRP, during summer of 2015

LB resistant germplasm	LB AUDPC and grain yield (t/ha)	NB resistant germplasm	NB score and yield (t/ha)	FB resistant germplasm	FB score and yield (t/ha)
ACC#405	20/1.32	ACC#2343	4/3.21	ACC#2752	0/2.62
ACC# 429	25/1.62	ACC#2374	4/2.64	ACC# 498	0/2.29
ACC#444	30/2.29	ACC#2627	4/3.58	ACC#2755	0/1.41
ACC#2746	30/1.05	ACC#2723	4/3.61	ACC# 2344	0/1.26
ACC#2752	35/2.62	ACC#2755	5/1.41	GE 0383	1/2.67
ACC#459	40/3.97	ACC#534	5/3.52	ACC#2291	2/3.21
ACC#428	40/2.91	ACC#460	6/3.90	ACC#519	2/3.82
ACC#520	40/1.46	ACC#2351	6/2.29	ACC#2351	3/2.29
ACC#463	45/3.25	ACC#2309	6/2.87	KK2	3/2.65
ACC#2304	45/3.24	ACC#530	6/3.23	ACC#2734	3/3.21
ACC# 425	45/3.14	L. CHECK	6/2.07	ACC#2289	3/3.76
ACC#464	45/2.83	ACC#2763	7/1.92	ACC#428	4/2.91
GE 507	45/2.83	ACC# 2356	7/1.65	ACC#522	4/3.15
ACC#6373	45/2.28	ACC#459	7/3.97	ACC#6373	5/2.28
KLE 298	45/2.00	NE 94	7/1.90	ACC#504	5/3.15
ACC#2745	45/1.86	ACC#2707	7/3.95	ACC#2428	6/2.92
ACC#2843	45/1.78	ACC#519	7/3.82	ACC#534	6/3.52
ACC#2356	45/1.69	ACC#458	7/2.73	ACC#2424	6/4.02
C1	72/2.47	C1	14.21/2.47	C1	18.35/2.47
C2	61/2.92	C2	15.28/2.92	C2	16.25/2.92

LB, leaf blast; NB, neck blast; FB, finger blast; t/ha, ton per hectare.

None of the high yielding germplasm was found resistant to all three blasts (leaf, neck and finger). Most of the high yielding germplasm showed moderately resistant to moderately susceptible reactions to blast disease and had higher number of bearing head per meter square and fingers per head. But ACC#2424, ACC#522, ACC#519 and ACC#2289 having yield capacity more than 3 t/ha were found resistant to finger blast. Germplasm ACC#463, ACC#459, ACC#425 and ACC#2304 showed resistance to leaf blast with yield capacity more than 3 t/ha. Most of the neck blast resistant germplasm showed higher yield than the national average.

Agronomic characters and grouping

Plant height ranged from 39-105 cm. Tested germplasm took maturity duration of 65-145 days. Likewise, bearing head per square meter ranged from 48-234 and fingers per head 4-11. While grouping the germplasm according to their plant height, different 9 groups were formed. In each group, visible morphological differences like head type during maturity, stem pigmentation and nodal pigmentation were observed with difference in yield and blast disease parameters.

Table 4. Identification of germplasm for cultivar mixture trials using different parameters

PH ranges (cm)	No. of gpms	Avg. PH (cm)	Avg. maturity days	Avg. yield	Head type during maturity	Stem pig.	Nodal pig.	Response to NB and FB
100-105	9	102 ±2	136.33 ±3.84	2.57±0.83	S, C and I	Both P and G	Both P and G	R, MR, MS, S
99-95	15	97 ±2	136.4 ±4.46	2.97±0.55	S, C and I	Both P and G	Both P and G	R, MR, MS
94-90	23	91 ±1	134.91 ±2.81	2.80±0.66	S, C and I	Only G	Both P and G	R, MR, MS,
89-85	33	87 ±1	135.6 ±3.66	2.71±0.81	S, C and I	Both P and G	Both P and G	R, MR, MS, S
84-80	27	81 ±1	135.94 ±4.15	2.50±0.70	S, C and I	All G	Both P and G	R, MR, MS, S
79-75	29	77 ±1	135.86 ±3.56	2.14±0.59	S, C and I	All G	Both P and G	R, MR, MS, S
74-70	10	72 ±1	134.8 ±3.19	1.80±0.69	S, C and I	All G	Both P and G	MR, MS
69-65	5	67 ±2	137.4 ±4.72	2.56±0.92	S, C and I	All G	All G	DF, MR, MS, S
<64	5	54 ±9	129.74 ±5	2.15±0.93	S and I	All G	Both P and G	MR, MS, S

Mean ± SD, PH, plant height; gpms, germplasm; Pig., pigmentation; NB, neck blast; Avg., average; FB, finger blast; S, spreading type; C, compact type; I, intermediate type; P, purple; G, green types of pigmentations in stem; DF, disease free; R, resistant; MR, moderately resistant; MS, moderately susceptible.

In group 1, all germplasm showed moderately resistant reaction to neck blast but moderately resistant to susceptible reaction to finger blast. Similarly, group 2 also contained both moderately resistant and moderately susceptible reactions showing germplasm. But group 4 contained resistant, moderately resistant, moderately susceptible and susceptible germplasm for both neck blast and finger blast with differences in morphology. Other groups also contained germplasm showing differential reactions to blast disease. From each group, mixture of germplasm with differences in morphology, disease responses and yielding capacity can be formed.

DISCUSSION

Differential reactions of finger millet germplasm to blast disease

Tested germplasm showed different level of responses to the blast disease (leaf, neck and finger blast) under natural epiphytotic conditions at HCRP during summer of 2015. It might be due to the different origin of the germplasm or different pathotypes of the blast fungus prevailing in the tested environment. Khadka et al (2013) also reported presence of diverse blast pathogen under HCRP field conditions. All the finger millet germplasm got infected by leaf blast but the disease score value for most of the tested genotypes decreased with increased plant age. It might be due to less humid condition in nursery and space maintained during the time of transplanting or presence of adult plant resistance property in finger millet as stated by Kiran Babu et al (2013).

Mean performance and distribution of agronomic traits

The highest yields of the top 10 germplasm among 156 revealed higher values at HCRP (2.47-4.06 t/ha) compared to national check Kabre Kodo-1 ie 2.9 t/ha (www.aicc.gov.np, 2015). Grain yield of the tested germplasm were found nearly normally distributed. The performance probably indicated the better environmental conditions for finger millet cultivation in HCRP or potentiality of germplasm to produce higher yield. Yield variations in finger millet germplasm were observed in similar way by Verma (1989).

Mean performance and distribution of leaf, neck and finger blast scores

Neck and finger blast scores were highly positively skewed. Leaf blast scores were also observed positively but moderately skewed. The availability of germplasm with disease score range from resistant, moderately resistant and susceptible for both neck and finger blast revealed availability of resistant as well as susceptible genes which can be exploited in the breeding program and in mixture preparation. The near normal moderately skewed distribution may suggest presence of several genes with quantitative effects (Ravikumar 1988)

Finger millet germplasm grouping for mixture

Use of the crops more or less similar in their phenotypic appearance and compatible in mixed cropping becomes pre-requisite for mixture determination (Finckh et al 2000, Mundt 1994). Growing mixtures of crop varieties that differ in their pathological response to reduce disease pressure is one of the promising strategies (Finckh and Wolfe 1997, Finckh and Wolfe 1998, Joshi et al 2018). Increased intra varietal diversity is also useful for minimizing the stresses (Joshi et al 2016). Bowden et al (2001) noticed that some time height difference may facilitate harvest but if the difference is too large it necessitates excessive attention to ensure that the entire crop is harvested in wheat. Which indicates use of crops with little height (5-10 cm) difference will be manageable as we grouped finger millet germplasm in **Table** 4. Mundt (1994) while studying host genetic diversity to control rice blast mentioned variation in maturity duration may create problem in cooler region but if maturity period coincide with hot and dry season will not affect much. This increased the reliability of grouping finger millet germplasm differ in maturity duration by 3-5 days in this study.

CONCLUSIONS AND RECOMMENDATIONS

Some genotypes like ACC#2424 (4.02 t/ha), ACC#522 (4.01 t/ha), ACC#519 (3.82 t/ha), ACC#2289, (3.76 t/ha) ACC#2723 (3.61 t/ha) and ACC#530 (3.23 t/ha) were found superior in blast resistance as well as in terms of grain yield. Other moderately susceptible but high yielding genotypes can be used in hybridization program to develop new varieties for the purpose of general cultivation under divergent climatic conditions. Genotypes having higher yield capacity but susceptible to blast disease like ACC#2408 (4.06 t/ha), ACC#2608 (3.95 t/ha), ACC#2707 (3.95 t/ha), ACC#2620 (3.93 t/ha) and ACC#460 (3.90 t/ha) can be used for mixed cultivation with resistant genotypes based on their suitability in other agronomic traits. Identification of germplasm superior to national check for blast disease resistance and agronomical traits widens the scope of this study. Resistant germplasm with low yielding capacity can be used in further breeding program and moderately resistant with high yielding capacity should be upgraded to multi-location yield trials. Germplasm with moderately susceptible reaction to blast disease with high yielding capacity may show resistant reactions in another location if pathotypes of the blast fungus vary there.

Grouping of germplasm according to their agronomic compatibility will be helpful in selection of germplasm to prepare cultivar mixture. Grouped germplasm according to their agronomic parameters contains germplasm showing differential response to blast disease. Therefore, cultivar mixture trial can be conducted selecting from each group to examine mixture effect in controlling blast disease for further study.

ACKNOWLEDGEMENTS

The assistance from Krishna Kumar Mishra, coordinator of HCRP, Dolakha; Krishna Hari Ghimire, Kiran Baral, Khem Raj Pant, Dinesh Kumar Nepali, Navaraj Subedi, Astha Bhushal and Mandira Dahal, are highly appreciated.

REFERENCES

Adhikari RK. 2012. Economics of finger millet (*Elecusine coracana* G.) production and marketing in peri urban area of Pokhara valley of Nepal. Journal of Development and Agricultural Economics **4**(6):151-157. 10.5897/JDAE11.119.

Batsa BK and DB Tamang. 1983. Preliminary report on the study of millet diseases in Nepal. **In**: Maize and Finger millet, 10th Summer Crops Workshop 1982, 23-28 Jan 1983, Rampur, Chitwan, Nepal.

Bowden R, J Shroyer, K Roozeboom, M Claassen and P Evans. 2001. Performance of Wheat Variety Blends in Kansas. Kansas State Univ. Agric. Ext. Bull. 128, www.oznet.ksu.edu/library/crpsl2/SRL128.pdf

Finckh MR and MS Wolfe. 1997. The use of biodiversity to restrict plant diseases and some consequences for farmers and society. **In**: Ecology in Agriculture (LE Jackson, ed); **pp**. 199–233.

Finckh MR and MS Wolfe. 1998. Diversification strategies. **In**: The Epidemiology of Plant Dis. (DG Jones, ed); **pp**. 231–59.

Finckh MR, ES Gacek, H Goyeau, C Lannou and U Merz. 2000. Cereal variety and species mixtures in practice. Agronomie **20**:813–37

HCRP. 2007. Finger millet research report. **In**: Annual Report 2007. Hill Crops Research Program (HCRP), Nepal Agricultural Research Council, Baiteshwor-4, Kabre, Dolakha, Nepal; **pp**.15-18.

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages. Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal, and BR Sthapit. 2017. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, NARC, and Bioversity International, Pokhara, Nepal.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020a. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, RC Prasad, SB Gurung, KH Ghimire, D Singh, S Gautam and AR Adhikari. 2016. Increasing intra and inter varietal diversity in rice, bean, common buckwheat and finger millet for managing disease, pest and climate uncertainty in mountain agriculture. **In**: LCP Virtual Workshop, Local crop project, Dec 2016.

Joshi BK, SP Vista, SB Gurung, KH Ghimire, R Gurung, S Pant, S Gautam and PB Paneru. 2020b. Cultivar mixture for minimizing risk in agriculture farming and conserving agrobiodiversity. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Karthikeyan V, SS Gnanamanickam, AC Amadioha. 2000. Biological control of *Setaria* blast (*Magnaporthe grisea*) with bacterial strains controlling rice blast in vitro and in vivo with extracts of *Azadirachta indica.* Crop Prot. **19**:287-290.

Khadka, RB, SM Shrestha, HK Manandhar and GB KC. 2013. Pathogenic variability and differential interaction of blast fungus (*Pyricularia grisea* Sacc.) isolates with finger millet lines in Nepal. J. Science and Technology **14**:17-24

Kiran Babu T, RP Thakur, HD Upadhyaya, PN Reddy, R Sharma, AG Girish and NDRK Sarma. 2013. Resistance to blast in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology **135**(2):299-311.

Mc Rae W. 1922. Report of the Imperial Mycologist. Indian Agricultural Research Institute. Pusa Sci. Reports 1921-22 44-50.

MoAD. 2017. Statistical Information on Nepalese Agriculture 2016/17. Singa Durbar, Kathmandu Nepal: Ministry of Agriculture and Development, Agri-Business Promotion and Statistics Division.

Mundt CC. 1994. Use of host genetic diversity to control cereal diseases: implications for rice blast. **In**: Rice Blast Disease, ed. S Leong, RS Zeigler, PS Teng; **pp**. 293–307.

Nagaraja A, PS Jagadish, EG Ashok and KT Krishne Gowda. 2007. Avoidance of finger millet blast by ideal sowing time and assessment of varietal performance under rainfed production situations in Karnataka. J. Mycopath. Res. **45**:237- 240.

Patro TSSK and J Madhuri. 2014. Epidemiological studies on blast disease of finger millet (*Eleusine coracana* Gaertn.). Indian Journal of Plant Sciences **3**(1):115-117.

Prasad RC. 2008. Finger millet research report. **In**: Annual Research Report. HCRP, Kabre, Dolakha, Nepal; **pp**.22-28

Ramappa HK, CR Ravishankar and P Prakash 2002. Estimation of yield loss and management of blast disease in finger millet (Ragi). **In**: Proceedings of Asian Conference Mycology Plant Pathology. University of Mysore, Mysore.

Ravikumar RL 1988. Genetic and biochemical basis of blast resistance in finger millet (*Eleusine coracana* Gaertn.). PhD Thesis, University of Agricultural Sciences, Bangalore, India.

Shaner G and R Finney. 1997. The effect of nitrogen fertilization on the expression of slow-mildewing in knox wheat. Phytopathology **36**:1307-1311

Sridhar R and UD Singh. 2001. Genetic and pathogenic diversity of the rice blast pathogen. **In**: Major Fungal Diseases of Rice, Recent Advances (S Sreenivasaprasad and R Johnson, eds); **pp**.1-7.

Tharanathan RN and S Mahadevamma. 2003. Grain legumes - a boon to human nutrition. Trends in Food Science and Technology **14:**507–518.

Upreti RP. 1993. National summer hill crops report 1992. **In**: Hill Crops Proceeding, National Hill Crops Research Program Kabre, Dolakha, Janakpur Zone, Nepal; **pp**.101-108.

Verma VS. 1989. Variability pattern in quantitative traits of ragi (*Eleusine coracana* (L) *Gaertn*). Madras Agric. J. **76**:626-629.

Vishwanath S, SS Gowda, A Seetharam and BTS Gowda. 1986. Reaction to blast disease of released and pre-released varieties of finger millet from different states. Millet Newsl. **5**:31.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project; Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Agro-morphological Diversity in Nepalese Finger Millet Landraces

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ABSTRACT

Finger millet is the fourth most important crop of Nepal grown mainly for food and feed. Genebank of Nepal holds more than 850 finger millet landraces collected from 54 districts of the country. To enhance the utilization of these landraces, a total of 300 finger millet accessions were characterized and evaluated in three sets of experiments: (i) characterization using morphological markers, (ii) screening for blast resistance at three hill locations Lalitpur (Khumaltar), Dolakha (Kabre) and Jumla (Bijayanagar), and (iii) screening for drought tolerance at Khumaltar for two consecutive years of 2017 and 2018. Sixteen quantitative and nine qualitative traits were recorded using standard finger millet descriptors to assess the diversity. Leaf, neck and finger blast were scored at blast screening nursery and yield as well as other drought-linked traits were recorded at drought screening experiments. Diversity was observed among the accessions as revealed by Shannon-Weaver diversity indices (H') for seven qualitative traits (0.569-0.799). During both the years, accessions showed great diversity for all the quantitative traits at all three locations. Most of the accessions showed resistant to moderately resistant reactions in both years at Bijayanagar and Kabre but moderately resistant reaction for leaf blast and moderately susceptible to susceptible reactions for neck and finger blasts in both years at Khumaltar. There was 35.6% and 12.7% reduction in grain yield due to drought imposition in the experiments of 2017 and 2018, respectively as compared to control. However, some accessions yielded even higher under drought over normal conditions. Eight landraces were identified superior compared to best released variety (Kabre Kodo-1) based on agro-morphological traits at all locations. These landraces are important genetic resources to develop finger millet varieties suitable for hilly and mountainous regions of Nepal as well as to understand genetics of finger millet.

Keywords: Blast, diversity, drought, finger millet landraces, quantitative traits, qualitative traits

INTRODUCTION

Finger millet [*Eleusine coracana* (L.) Gaertn.] is an important food crop in the lives of some of the poorest inhabitants. It is widely grown in India, Myanmar, Nepal, Sri Lanka, China and Japan in Asia and Uganda, Tanzania, Kenya, Ethiopia, Rwanda and Somalia in Africa (Upadhyaya et al 2010). It is a tetraploid species ($2n=4x=36$; genome constitution AABB) of the grass family *Poaceae* (Dida et al 2008). It was domesticated about 3000 BC in East Africa (possibly Ethiopia) and introduced into India, 1000 BC (Hilu et al 1979). Precise data of area and production under finger millet in many countries is not available because the production statistics of this crop had often been clubbed with other millets. The Consultative Group on International Agricultural Research (CGIAR) has estimated that 10% of the area under millets is with finger millet. Nutritionally, its importance is well recognized because of its high content of calcium (0.38%), dietary fiber (3.6%) and phenolic compounds (0.3-3%) (Devi et al 2011). The crop is also recognized for its health beneficial effects, such as anti-diabetic, anti-tumorigenic, atherosclerogenic effects, antioxidant and antimicrobial properties (Devi et al 2011, Kumar et al 2016).

Finger millet (*Kodo* in Nepali) is the fourth most important crop of Nepal after rice, maize and wheat in terms of area and production. It occupies an average of 7.7% (263,497 ha) of the total cultivated area covered by cereal crops and accounts for 3.1% (313,987 tons) of total cereal production (MoALD 2019). It has been cultivated from Tarai (Kachorwa, Bara: 85 masl) to high Mountains (Burounse, Humla: 3130 masl) in Nepal (Amgain et al 2004, Baniya et al 1992) with cultivation record from all 77 districts. A total of 237,862 tons (77%) of finger millet produced was from hill districts followed by 61,417 tons (20%) from mountain districts but its productivity is almost static (1.17 to 1.19 t/ha) in the last 30 years (Ghimire et al 2017, MoALD 2018) with very low priority, releasing only five varieties in 45 years of research (Joshi et al 2017). Finger millet has a wide range of utility in Nepal as its flour is commonly used for making *dhindo, roti* and grain is used for making high quality traditionally fermented liquors called *raksi*. Since it is a hardy crop grown in marginal land and stress environments with high nutritional contents, it is considered as the future smart crop with great potentiality to cope with national and global food and nutrition insecurity in the context of climate change. However, 40% of crop genetic diversity has been lost mainly because 85% of native genetic resources including finger millet are neglected and underutilized (Joshi et al 2020).

After the establishment of Genebank in 2010, collection and conservation of finger millet germplasm got high priority, holding more than 850 finger millet genetic resources in medium and long-terms conservation (Ghimire et al 2015, Ghimire et al 2017). Developing high yielding varieties for non-stress environments is always given high priority in the breeding program since it is easier to show the impact of the research system. But breeding for biotic and abiotic stress resistance for a crop like finger millet is always in low priority in global as well as national research systems. Biotic stresses mainly diseases are a cause for substantial yield losses of millets. Blast (*Pyricularia grisea*) is the major yield limiting factor of finger millet worldwide and also in Nepal. It damages the foliage, neck and finger at different growth stages of the crop. Severe yield reduction will be observed if blast infects prior to milking stage of the crop. The disease development is favored by lower temperature with higher relative humidity and causes epidemic of leaf or neck or finger blast (Manandhar et al 2016). In semi-arid and arid environments where millets are the dominant crop, drought is the major abiotic stress affecting productivity (Tadele 2016). Continuous drought in recent years was the major production constraint in the mid and far-western hills and mountains where finger millet is the main staple crop.

The phenotypic variability of finger millet was reported by several workers and most of these works have been done in India. Upadhyaya et al (2006) developed a set of core collection in finger millet based on agro-morphological diversity which constituted 622 accessions (10.47%) from the entire collection of 5940 accessions conserved in the Genebank of International Crop Research Institute for Semi-Arid Tropics (ICRISAT). Little works have been done on the characterization of Nepalese finger millet accessions. Agro-morphological characterization done at Genebank, Khumaltar showed high diversity among 537 Nepalese germplasm accessions (Bhattarai et al 2014) and similar results among 50 landraces were reported from the experiment conducted at Rampur, Chitwan based on agro-morphological traits (Bastola et al 2015). The natural variations present within landraces are important for selection and development of varieties for the different agro-climatic regions of Nepal, since creation of diversity artificially is tedious and bit difficult due to limited resources. Identifying suitable genotypes from existing accessions for biotic and abiotic stress resistance is one of the current thrust areas of finger millet research in Nepal (HCRP 2018). Pre-breeding is an essential activity of Genebank to improve utilization of genetic resources collected and conserved ex-situ. Characterization of collected landraces is the most important avenue to open the door for their utilization. However, less utilization of local genetic resources for crop improvement program is evident due to lack of information about the desirable accessions in Genebank resulting from the poor characterization and evaluation data. The specific objectives of the study were to characterize diverse finger millet germplasm and screen them for blast resistance and drought tolerance to facilitate their use in breeding program.

MATERIALS AND METHODS

Experimental sites

Experiments were conducted at three mountain locations of Nepal, namely Agriculture Research Station (ARS) Bijayanagar, Jumla (2350 masl); National Agriculture Genetic Resources Centre (NAGRC, Genebank), Khumaltar, Lalitpur (1360 masl) and Hill Crops Research Program (HCRP), Kabre, Dolakha (1740 masl) during summer season of two consecutive years 2017 and 2018. Experimental locations and their geo-coordinates were mapped in **Figure** 1. All the three sites have coarse textured (sandy loam) soil. Rainfall and temperature of the three sites during finger millet growing season (May to November) of the both years has been presented in **Table** 1.

Table 1. Meteorological data of three experimental sites during two experimental seasons (May to November)

Climatic parameters	ARS, Bijayanagar		NAGRC, Khumaltar		HCRP, Kabre	
	2017	2018	2017	2018	2017	2018
Minimum temperature (°C)	11.4	11.7	17.2	16.6	16.7	17.4
Maximum temperature (°C)	24.0	24.8	27.5	27.0	24.4	24.7
Total rainfall (mm)	723	687	937	950	2369	1981

Source: ARS 2017, ARS 2018, ARS 2019, Genebank 2017, Genebank 2018, Genebank 2019, HCRP 2017, HCRP 2018, HCRP 2019.

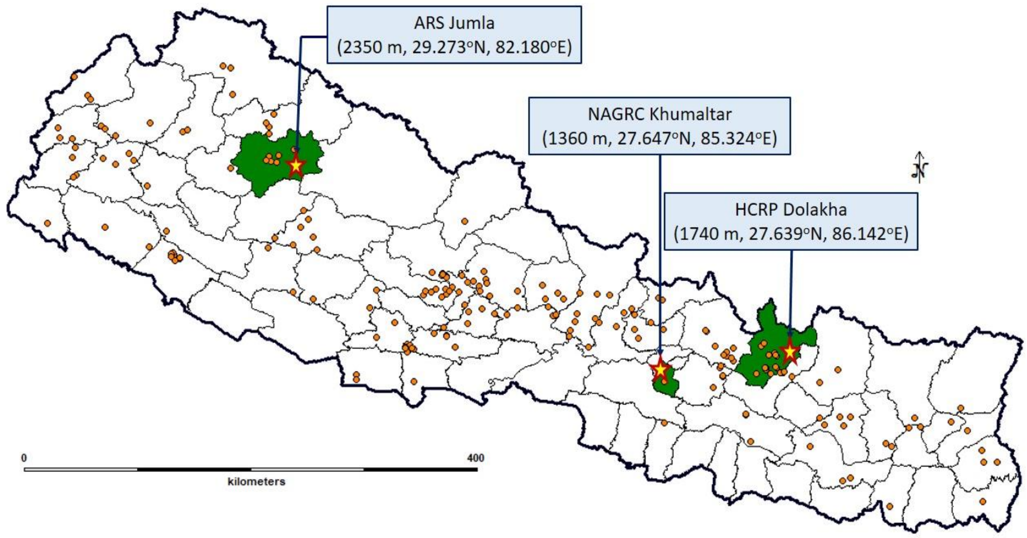

Figure 1. Map of Nepal showing collection sites (circles) of characterized finger millet accessions and three experimental sites (stars).

Plant materials

Among more than 850 collections of finger millet in Genebank, this study included 300 finger millet accessions, out of these, 295 were landraces collected from 55 districts of Nepal and five were released varieties (Okhle-1, Dalle Kodo-1, Kabre Kodo-1, Kabre Kodo-2 and Shailung Kodo-1) collected from HCRP, Dolakha (**Figure** 1, 2).

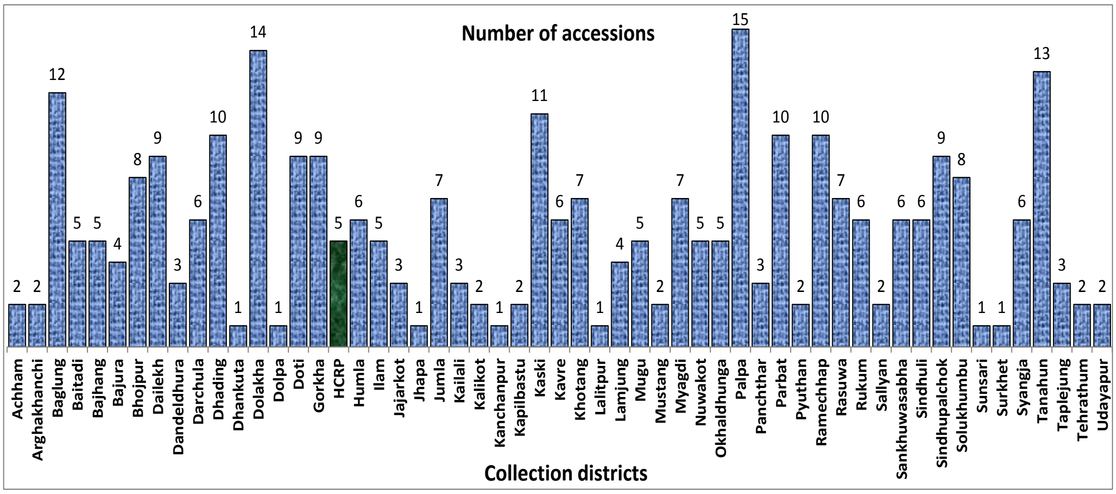

Figure 2. District-wise number of accessions used in the study (5 released varieties from HCRP and 295 landraces from 54 districts).

General methodology

There were three objectives based experiments: 1. characterization, 2. screening for blast resistance, and 3. screening for drought tolerance. All three experiments were laid out in alpha lattice design with 300 entries and three replications having 15 blocks within replications and 20 plots in each block. Direct seeding method was followed in all the experiments with the application of chemical fertilizers at the rate of 20:10:10 kg/ha $N:P_2O_5:K_2O$ as basal doses. In blast screening experiment, additional 40 kg/ha N was top dressed in two split doses at 30 and 50 days after seeding. Plot size, spacing and seeding dates are presented in **Table** 2. Three rows of maize as wind breaks were planted a month earlier than the test entries followed by four spreader rows of susceptible mixture of finger millet at one-week interval to create a conducive environment for the blast disease. Drought screening experiment was planted in raised bed under white plastic roofed structure to prevent from rainfall. Light irrigation was given in every two weeks till flowering initiation and no irrigation was provided afterwards. Soil moisture at the depth of 10 cm was measured in every alternate day from both drought as well as characterization field.

Table 2. Methodological summary of all experiments at three sites during two years

Experimental Details	ARS, Bijayanagar		NAGRC, Khumaltar		HCRP, Kabre	
	2017	2018	2017	2018	2017	2018
1. Characterization						
Plot size	0.5 m^2	0.5 m^2	0.5 m^2	0.5 m^2	0.5 m^2	0.5 m^2
Spacing (cm)	25×10	25×10	25×10	25×10	25×10	25×10
Date of seeding	24 April	19 April	17 June	7 June	3 June	26 May
2. Screening for blast resistance						
Plot size	0.1 m^2	0.1 m^2	0.1 m^2	0.1 m^2	0.1 m^2	0.1 m^2
Spacing (cm)	10×5	10×5	10×5	10×5	10×5	10×5
Date of seeding	8 May	5 May	21 July	21 June	24 June	14 June
3. Screening for drought tolerance (only one location)						
Plot size	-	-	0.2 m^2	0.2 m^2	-	-
Spacing	-	-	20×10	20×10	-	-
Date of seeding	-	-	28 July	8 July	-	-

Data recording and analysis

Morphological data of nine qualitative and 16 quantitative traits were recorded using the standard descriptors for finger millet (IBPGR 1985). The qualitative traits were recorded from single replication at Khumaltar only, based on the observation of descriptor states whereas the quantitative traits were recorded by count and measurement. Observations on days to flowering and maturity as well as measurement of grain yield were based on whole plot data whereas measurements on other quantitative traits such as plant height, leaf lengths, finger lengths, leaf sheath lengths, etc were made from five randomly selected plants. Shannon Weaver Diversity indices (Shannon and Weaver 1949) were calculated for each qualitative trait with Microsoft Excel using the formula:

$$H' = \left[\sum \left(\frac{n}{N}\right) * \left\{log2\left(\frac{n}{N}\right) * (-1)\right\}\right] / log2k$$

Where, H' is the standardized Shannon Weaver Diversity Index, k is the number of phenotypic classes for a character, n is the frequency of a phenotypic class of that character and N is the total number of observations for that character.

Frequency of each descriptor states for each qualitative trait were tabulated. The quantitative data were analyzed for descriptive statistics using Minitab-17 (Minitab 2010). Leaf blast was scored in 0-9 scale (Kiran Babu et al 2013, Manandhar et al 2016) and reactions were simplified as: resistant (0-1), moderately resistant (2-3), moderately susceptible (4-5), susceptible (6-7) and highly susceptible (8-9) (HCRP 2017) whereas neck and finger blasts were scored based on 1-5 scale as described by Kiran Babu et al (2013).

RESULTS AND DISCUSSION

Diversity index and frequency distribution of qualitative traits

Shannon-Weaver diversity index (H') considers both richness and evenness of the phenotypic classes of the qualitative traits. Table 3 showed medium (H'=0.569 for lodging) to high (H'=0.799 for ear shape) level of diversity among the accessions for most of the qualitative traits but there was no diversity among the accessions for finger branching and spikelet shattering. Thirty-nine percent of finger millet accessions were having open heads or ears followed by 37% semi-compact heads. Sixty-five percent of accessions had intermediate size of ears followed by 30% large ears. Bhattarai et al (2014) had also reported 62% of the accessions with intermediate ear size at Khumaltar. Eighty percent of the accessions had pigmented plants while 51% accessions had light-brown seed color followed by 42% had purple-brown colored seeds. Similar proportion of light-brown (45%) and purple-brown (47%) grain color was also reported by Bhattarai et al (2014).

Table 3. Shannon-Weaver diversity indices, descriptor states and frequency of nine qualitative traits of finger millet at Khumaltar, 2017

Qualitative trait	S-W diversity index (*H'*)	Descriptor states	Frequency (n)	Proportion (%)
Ear shape	0.799	Droopy	67	23.1
		Open	112	38.6
		Semi compact	109	37.4
		Compact	2	0.7
Ear size	0.725	Small	15	5.0
		Intermediate	188	64.7
		Large	88	30.2
Finger branching	0.000	Absent	295	100
		Present	0	0.0
Grain covering by glumes	0.691	Exposed	36	12.6
		Intermediate	207	73.7
		Enclosed	38	13.5
Lodging score	0.569	Low	215	73.4
		Intermediate	76	25.8
		High	3	0.9
Plant pigmentation	0.722	Not pigmented	236	80.1
		Pigmented	59	19.9
Seed color	0.678	White	9	3.0
		Light-brown	147	50.9
		Copper-brown	11	3.6
		Purple-brown	123	42.5
Spikelet density	0.716	Sparse	87	30.0
		Intermediate	189	65.2
		Dense	14	4.7
Spikelet shattering	0.000	Absent	295	100
		Present	0	0.0

Descriptive statistics of quantitative traits

Mean, standard error of mean and range of different quantitative traits observed in 2017 and 2018 have been presented in Table 4, 5, respectively. During 2017, accessions started flowering from 48 days and ended in 123 days at Khumaltar but ranged from 62 to 129 days at Kabre and 83 to 175 days at Bijayanagar. On an average, genotypes matured in 147 and 148 days at Khumaltar and Kabre, respectively, however, 55 accessions were found very late and didn't mature at Bijayanagar. Average plant height was 79 cm at Khumaltar, 82 cm at Kabre and 115 cm at Bijayanagar. Mean grain yield at Khumaltar, Kabre and Bijayanagar were recorded as 1446, 1358 and 1831 kg/ha, respectively.

Table 4. Descriptive statistics of 16 quantitative traits of finger millet accessions, 2017

Trait	NAGRC, Khumaltar		HCRP, Kabre		ARS, Bijayanagar	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
Days to flowering	48-123	95 ±0.68	62-129	104 ±0.53	83-175	133 ±0.80
Days to maturity	100-181	147 ±0.7	124-179	148 ±0.41	130-189	164 ±0.57
Plant height (cm)	29-127	79 ±0.6	12-157	82 ±0.76	30-188	115 ±0.82
Tillers/hill	1.0-6.4	2.8 ±0.03	1.0-14.6	6.0 ±0.08	2.0-5.4	3.8 ±0.02
Flag leaf length (cm)	15.5-47	29.8 ±0.18	4.0-38	24.4 ±0.17	16-44	29 ±0.16
Flag leaf width (cm)	0.6-1.4	1.0 ±0.01	0.4-0.9	0.6 ±0.03	0.7-1.5	0.9 ±0.02
Leaf sheath length (cm)	5.9-13.2	9.6 ±0.05	3-22	10.2 ±0.09	1.2-39	28 ±0.19
Panicle exertion (cm)	2.6-19.8	12.1 ±0.11	3-21.8	12.9 ±0.13	-	-
Ear head length (cm)	2.8-16.2	7.1 ±0.1	2.8-14.6	6.1 ±0.08	1.6-15.2	5.9 ±0.08
Ear head width (cm)	-	-	2.1-15.8	5.8 ±0.08	1-10.8	3.7 ±0.07
Length of finger (cm)	2.4-13.7	6.2 ±0.08	2.4-13.8	5.9 ±0.07	2.4-11.2	5.5 ±0.07
Width of finger (cm)	-	-	0.2-1.8	0.6 ±0.01	0.3-1.7	0.8 ±0.01
Fingers/head	2.0-11.8	6.6 ±0.1	2-15.6	6.9 ±0.07	4.6-12	7.8 ±0.05
Weight/head (g)	1.3-12.1	5.2 ±0.08	0.8-15	6.1 ±0.11	3.4-20.6	9.6 ±0.16

Trait	NAGRC, Khumaltar		HCRP, Kabre		ARS, Bijayanagar	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
1000 grain weight (g)	1.2-3.56	2.3 ±0.02	0.5-4.55	2.2 ±0.03	-	-
Grain yield (kg/ha)	36-7263	1446±42.2	5-5728	1358±42.1	0-6681	1831±67.8

During 2018, days to flowering ranged from 57-126 at Khumaltar, 62-141 at Kabre and 73-175 at Bijayanagar. Similarly, accessions were diverse for days to maturity ranged from 112-193 at Khumaltar and 90-210 at Kabre. Mean grain yield at Khumaltar, Kabre and Bijayanagar were recorded 1475, 1274 and 2001 kg/ha, respectively. At Bijayanagar, early accessions started to mature from 144 days but 213 accessions were very late and didn't matured due to severe cold. Early maturity is very important adaptive trait for Karnali region to escape from drought stress during grain filling stage and from extreme cold temperature during maturity. Similar result was reported by Bhattarai et al (2014) and Bastola et al (2015) from the characterization of Nepalese accessions but wider range was reported from the characterization of global finger millet population (Upadhyaya et al 2006, 2010).

Table 5. Descriptive statistics of 15 quantitative traits of finger millet accessions, 2018

Trait	NAGRC, Khumaltar		HCRP, Kabre		ARS, Bijayanagar	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
Days to flowering	57-126	101 ±1.04	62-141	104 ±0.65	73-175	136 ±0.72
Days to maturity	112-193	154 ±1.02	90-210	144 ±0.81	144-213	175 ±0.56
Plant height (cm)	75-142	111 ±0.71	34-133	89 ±0.64	29-130	93 ±0.65
Tillers/hill	1.1-5.4	2.2 ±0.04	1.8-7.3	3.7 ±0.04	2.2-15	7.5 ±0.13
Flag leaf length (cm)	19.9-39.8	29.4 ±0.21	5.3-36.8	23.9 ±0.20	11.1-40	26 ±0.19
Flag leaf width (cm)	0.8-1.4	1.1 ±0.01	0.34-1.6	1.0 ±0.02	0.3-1.3	0.9 ±0.01
Leaf sheath length (cm)	5.5-18.1	10.1 ±0.11	5.1-26.7	9.8 ±0.08	10-33	24 ±0.14
Panicle exertion (cm)	4-18	10.2 ±0.16	4.8-33.5	13.0 ±0.13	2.3-11.7	5.3 ±0.06
Ear head width (cm)	-	-	1.5-8.2	3.7 ±0.04	1.5-6.7	3.4 ±0.03
Length of finger (cm)	2.5-14.4	7.8 ±0.11	1.3-11.2	5.2 ±0.06	2.1-9.9	4.8 ±0.07
Width of finger (cm)	-	-	0.2-2.8	0.76 ±0.01	0.2-1.3	0.6 ±0.01
Fingers/head	4.6-9.9	7.3 ±0.06	2.0-11.6	6.6 ±0.07	3.8-13	7.0 ±0.06
Weight/head (g)	-	-	0.87-72.5	28.5 ±0.45	2.0-80	19 ±0.39
1000 grain weight (g)	1.3-3.9	2.4 ±0.02	-	-	-	-
Grain yield (kg/ha)	247-6512	1475±52.2	32-4698	1274±31.5	0-6327	2001±56.5

Screening for blast resistance

Frequency of five reaction levels for leaf, neck and finger blasts among the 300 accessions are presented in **Table** 6. The level of incidence of all blast diseases was higher during first year as compared to second year. Most of the accessions showed resistant to moderately resistant reactions in both the years at Bijayanagar and Kabre but moderately resistant reaction for leaf blast and moderately susceptible to susceptible reactions for neck and finger blasts at Khumaltar. None of the accessions were free from finger blast at Khumaltar and Kabre during 2018. At Bijayanagar, 98% of the accessions showed resistant and rest of the accessions showed moderately resistant reactions for leaf blast during 2017 but 55%, 44% and 1% accessions showed resistant, moderately resistant and moderately susceptible reactions during 2018. Susceptibility level for all three blast diseases was the highest at Khumaltar in both the years followed by Kabre and Bijayanagar.

Table 6. Reactions of 300 finger millet accessions to blast diseases at Bijayanagar, Khumaltar and Kabre in 2017 and 2018

Reaction	ARS, Jumla			NAGRC, Khumaltar			HCRP, Kabre		
	Leaf Blast	Neck blast	Finger blast	Leaf blast	Neck blast	Finger blast	Leaf blast	Neck blast	Finger blast
2017									
R	295	249	197	56	33	32	107	223	54
MR	5	36	43	214	93	64	192	57	62
MS	0	0	2	26	130	114	1	12	161
S	0	0	0	4	44	73	0	4	19
HS	0	0	0	0	0	17	0	4	4

Reaction	ARS, Jumla			NAGRC, Khumaltar			HCRP, Kabre		
	Leaf Blast	Neck blast	Finger blast	Leaf blast	Neck blast	Finger blast	Leaf blast	Neck blast	Finger blast
NO	-	15	58	-	-	-	-	-	-
2018									
R	164	45	3	4	4	0	1	2	0
MR	132	95	66	213	35	0	268	23	0
MS	4	130	162	83	65	6	31	101	45
S	0	30	49	0	144	133	0	130	214
HS	0	0	1	0	52	161	0	44	41
NO	-	-	19	-	-	-	-	-	-

R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible; HS, highly susceptible; NO, not observed.

Screening for drought tolerance

Average soil moisture taken at root zone depth (10 cm) from both drought screening field as well as normal open field in both the years has been presented in **Figure** 3. After 35 days of seeding when irrigation was stopped, average soil moisture was recorded 9% in the first year but 16% in the second year, which was reached below 6% after 85 days in first year but after 110 days in second year. Grain yield under drought and that under open field has been presented in **Figure** 4, 5. Average grain yield under drought was 933 kg/ha as compared to 1450 kg/ha under open field (control) during 2017 but it was 1531 kg/ha as compared to 1752 kg/ha during 2018. There was 35.6% reduction in grain yield in 2017 due to drought imposition in the experiment as compared to control (open field) whereas in 2018, the reduction was only 12.7%. This suggested that the drought stress imposed to the entries was severe in the first year but mild in the second year. However, at least 35 accessions produced higher grain yield under drought during 2017 and 60 accessions produced higher yield under drought over control during 2018.

Promising accessions

Ten promising landraces were selected for each environment based on grain yield, maturity, ears size, disease resistance, etc (**Table** 7). Some landraces such as NGRC04789, NGRC04849 and NGRC06490 were found promising at Khumaltar under normal as well as drought conditions. Similarly, NGRC03644, NGRC04804, NGRC06487 and NGRC06490 were the promising genotypes at Khumaltar and Kabre while NGRC04727 was found promising at Kabre and Bijayanagar environment. These landraces were superior to released varieties (Okhle-1, Dalle Kodo-1, Kabre Kodo-1, Kabre Kodo-2 and Shailung Kodo-1) at all locations and selected for further evaluation in coordinated trials by HCRP. These landraces could be considered as important genetic resources to develop finger millet varieties suitable for hilly and mountainous regions of Nepal.

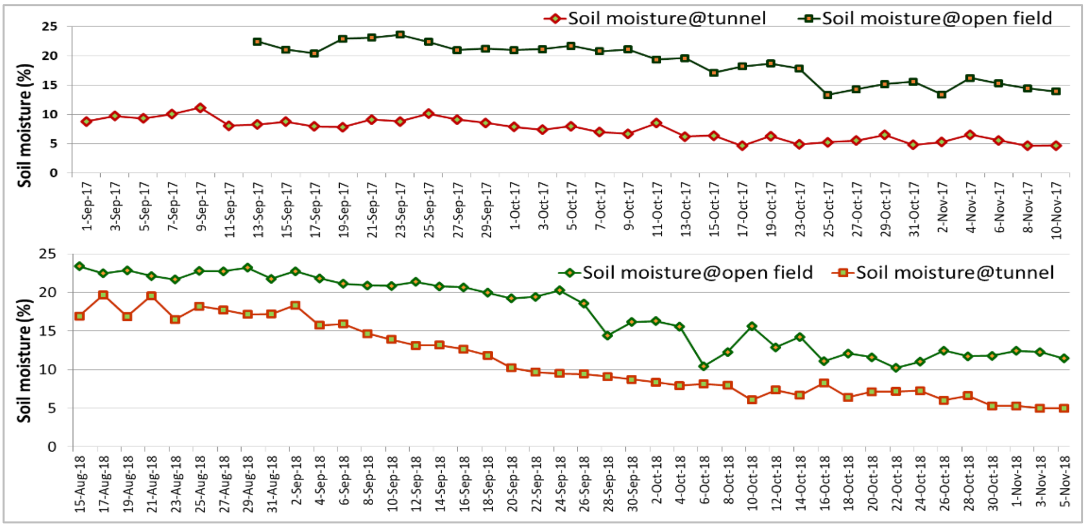

Figure 3. Average soil moisture (%) at 10 cm depth of experimental field during crop period of 2017 (top) and 2018 (bottom) at Khumaltar.

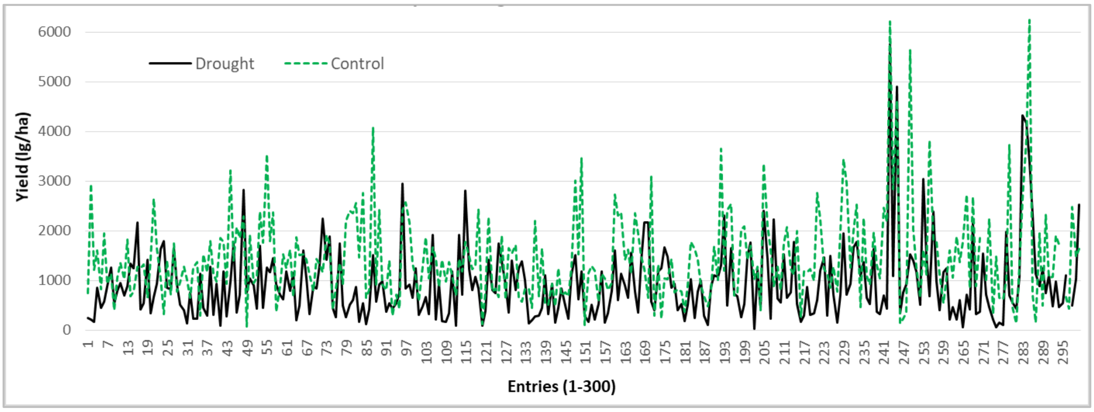

Figure 4. Line graph of grain yield under drought and control condition at Khumaltar, 2017.

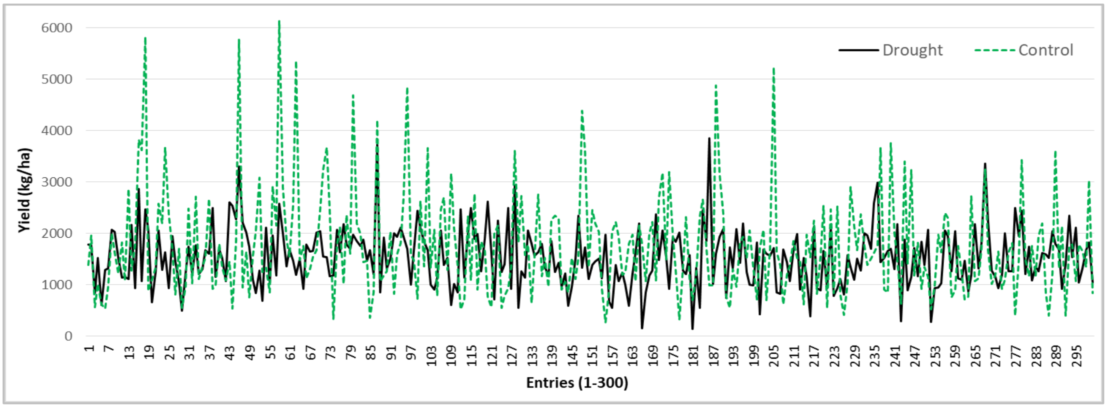

Figure 5. Line graph of grain yield under drought and control condition at Khumaltar, 2018.

Table 7. Promising finger millet accessions selected at Khumaltar, Kabre and Bijayanagar

Khumaltar (normal)		Khumaltar (drought)		Kabre		Bijayanagar	
Accession	**District**	**Accession**	**District**	**Accession**	**District**	**Accession**	**District**
NGRC01656	Mugu	NGRC01455	Kaski	NGRC04804	Dolakha	NGRC01512	Rukum
NGRC03486	Dhading	NGRC01539	Myagdi	NGRC04817	Dailekh	NGRC01649	Jumla
NGRC03586	Doti	NGRC01546	Baglung	NGRC04871	Udayapur	NGRC01652	Kalikot
NGRC04769	Ilam	NGRC03491	Dolakha	NGRC05765	Kaski	NGRC01653	Dolpa
NGRC06487	Sindhuli	NGRC03644	Dadeldhura	NGRC03644	Dadeldhura	NGRC03589	Jumla
NGRC04804	Dolakha	NGRC03674	Dolakha	NGRC03683	Rasuwa	NGRC03635	Doti
NGRC04836	Bajhang	NGRC05126	Baglung	NGRC04727	Dadeldhura	NGRC04727	Dadeldhura
NGRC04789	Kavre	NGRC04789	Kavre	NGRC06483	Tanahun	NGRC04732	Baitadi
NGRC04849	Rukum	NGRC04849	Rukum	NGRC06487	Sindhuli	NGRC04798	Ramechhap
NGRC06490	Sindhuli	NGRC06490	Sindhuli	NGRC06490	Sindhuli	NGRC05739	Palpa

CONCLUSIONS AND RECOMMENDATIONS

Three hundred finger millet landraces collected from 54 districts of Nepal were found to be diverse in morphology as validated by Shannon-Weaver diversity indices (*H'*) for the seven qualitative traits (0.57 to 0.799) whereas location specific performance was observed among the landraces for various quantitative traits. Most of the accessions showed resistant to moderately resistant reactions to major finger millet diseases (leaf, finger and neck blast) in both years at Bijayanagar and Kabre but moderately resistant reaction for leaf blast and moderately susceptible to susceptible reactions for neck and finger blast in both years at Khumaltar. Landraces such as NGRC04789, NGRC04849 and NGRC06490 were found promising at Khumaltar under normal as well as drought conditions. Similarly, NGRC03644, NGRC04804, NGRC06487 and NGRC06490 were the promising genotypes at Khumaltar and Kabre while NGRC04727 was found promising at Kabre and Bijayanagar environment. The diversity among Nepalese finger millet landraces is a great asset for the breeders and researchers. Characterization data with agro-morphological markers should be tied up with the data with molecular markers to further validate these results. Pre-breeding activities should be strengthened to identify disease resistant and drought tolerant landraces and to bridge the gap between Genebank and HCRP programs regarding the utilization of local landraces. Promising landraces superior to all released varieties, need to be registered and brought into the formal seed system for their conservation and sustainable use as well as to contribute in the national food and nutrition security.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the technical support from Mr Netra Hari Ghimire and Dr Sri Prasad Vista from ARS, Bijayanagar, Jumla; Dr Mina Nath Poudel, Sanjay Karki and Niru KC from NAGRC Khumaltar, Lalitpur; Mr Narayan Bahadur Dhami and Dinesh Nepali from HCRP, Kabre, Dolakha; Dr Devra Jarvis and Safal Khatiwada from Bioversity International. We extend our sincere gratitude to all those farmers who provided seeds of these landraces.

REFERENCES

ARS. 2017. Annual Report 2073/74 (2017). Agriculture Research Station, NARC, Vijayanagar, Jumla, Nepal.

ARS. 2018. Annual Report 2074/75 (2018). Agriculture Research Station, NARC, Vijayanagar, Jumla, Nepal.

ARS. 2019. Annual Report 2075/76 (2019). Agriculture Research Station, NARC, Vijayanagar, Jumla, Nepal.

Amgain RB, BK Joshi, P Shrestha, B Chaudahry, NP Adhikari and BK Baniya. 2004. Intra- and interpopulation variation in finger millet (*Eleusine coracana* (L.) Gaertn) landraces grown in Kachorwa, Bara, Nepal. **In**: On-farm Conservation of Agricultural Biodiversity in Nepal. Volume 1: Assessing the Amount and Distribution of Genetic Diversity On-farm (BP Sthapit, MP Upadhyay, PK Shrestha and DI Jarvis, eds.). Proceedings of the Second National Workshop, Nagarkot, Nepal, August, 25-27, 2004; **pp**.84-95.

Baniya BK, KW Riley, DMS Dongol and KK Sherchand. 1992. Characterization of Nepalese hill crops landraces (Barley, Buckwheat, Finger millet, Grain Amaranth, Foxtail, Proso and Barnyard millets). NARC-IBPGR, Kabre, Dolakha, Nepal; **pp**.162.

Bastola BR, MP Pandey, BR Ojha, SK Ghimire and K Baral. 2015. Phenotypic diversity of Nepalese finger millet accessions at IAAS Rampur, Nepal. *Int. J. Appl. Sci. Biotechnol*. **3**(2):285-290.

Bhattarai M, KH Ghimire, BK Joshi and MR Bhatta. 2014. Characterization of finger millet (*Eleusine coracana* Gaertn.) germplasm with agro-morphological markers. **In**: Proceedings of the 27th National Summer Crops Workshop: Volume-II; Nepal Agricultural Research Council; **pp**.184-189.

Devi PB, R Vijayabharathi, S Sathyabama, NG Malleshi and VB Priyadarisini. 2011. Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: a review. J. Food Sci. Technol. **51**(6):1021–1040.

Dida MM, N Wanyera, ML Harrison Dunn, JL Bennetzen and KM Devos. 2008. Population structure and diversity in finger millet (*Eleusine coracana*) germplasm. Tropical Plant Biol. **1**:131-141.

Genebank. 2017. Annual Report 2073/74 (2016/17). National Agriculture Genetic Resources Centre, NARC (BK Joshi, KH Ghimire, D Singh, A Karkee, and S Shrestha, eds). Khumaltar, Lalitpur, Nepal.

Genebank. 2018. Annual Report 2074/75 (2017/18). National Agriculture Genetic Resources Centre. NARC (BK Joshi, KH Ghimire, A Karkee, RP Mainali, P Thapa, S Shrestha, eds). Khumaltar, Lalitpur, Nepal.

Genebank. 2019. Annual Report 2075/76 (2018/19). National Agriculture Genetic Resources Centre. NARC (KH Ghimire, D Singh and A Karkee, eds). Khumaltar, Lalitpur, Nepal.

Ghimire KH, B Bhandari, SB Gurung, NB Dhami and BK Baniya. 2017. Diversity and utilization status of millest genetic resources in Nepal. Proceedings of 2nd National Workshop on Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal. http://www.moad.gov.np/en/publication/index?page=2

Ghimire KH, HB KC, BK Joshi and MR Bhatta. 2015. Plant genetic resources and agriculture in Nepal. **In**: Proceedings of AFACI Country Reports, 3rd International Training Workshop on Germplasm Management System, 11-20 May 2015. Rural Development Administration (RDA), Jeonju, Republic of Korea.

HCRP. 2017. Annual Report 2073/74 (2016/17). Hill Crops Research Program, NARC. Kabre, Dolakha, Nepal.

HCRP. 2018. Annual Report 2074/75 (2017/18). Hill Crops Research Program, NARC. Kabre, Dolakha, Nepal.

HCRP. 2019. Annual Report 2075/76 (2018/19). Hill Crops Research Program, NARC. Kabre, Dolakha, Nepal.

Hilu KW, JMJ de Wet and JR Harlan. 1979. Archaeobotanical study of *Eleusine coracana* ssp. *coracana* (finger millet). Crop Evolution Laboratory, University of Illinois, Urbana 61801. Amer. J. Bot. **66**(3):330-333.

IBPGR. 1985. Descriptors for Finger millet. International Board for Plant Genetic Resources Secretariat, Rome, Italy. http://www.bioversityinternational.org

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal and BR Sthapit. 2017. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, Pokhara; NARC, Kathmandu and Bioversity International, Pokhara, Nepal.

Joshi BK, NA Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020. Agro-biodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33. https://doi.org/10.3126/jnarc.v6i0.28111

Kiran Babu T, RP Thakur, HD Upadhyaya, PN Reddy, R Sharma, AG Girish and NDRK Sarma. 2013. Resistance to blast (*Magnaporthe grisea*) in a mini-core collection of finger millet germplasm. *European Journal of Plant Pathology* **135**(2):299-311.

Kumar A, M Metwal, S Kaur, AK Gupta, S Puranik, S Singh, M Singh, S Gupta, BK Babu, S Sood and R Yadav. 2016. Nutraceutical value of finger millet [*Eleusine coracana* (L.) Gaertn.], and their improvement using omics approaches. *Frontiers in Plant Science*. doi:10.3389/fpls.2016.00934.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhe, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis and BR Sthapit. 2016. A Field Guide for Identification and Scoring Methods of Diseases in the Mountain Crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

MINITAB. 2010. Minitab 17 Statistical Software. State College, Pennsylvania: Minitab, Inc. www.minitab.com

MOALD. 2018. Statistical Information on Nepalese Agriculture, 2016/2017. Government of Nepal. Ministry of Agriculture Development, Agri-Business Promotion and Statistics Division, Singha Durbar, Kathmandu, Nepal.

MOALD. 2019. Krishi Diary-2076. Agriculture Information and Training Centre (AITC), Hariharbhawan, Lalitpur, Nepal (In Nepali language).

Shannon CE and W Weaver. 1949. The Mathematical Theory of Communication. The University of Illinois, Chicago; **pp**.3-24.

Tadele Z. 2016. Drought Adaption in Millets. **In**: Biotic and Abiotic Stress in Plants - Recent Advances and Future Perspectives (AK Shanker and C Shanker, eds). Downloaded from: http://www.intechopen.com

Upadhyaya HD, CLL Gowda, RPS Pundir, VG Reddy and S Singh. 2006. Development of core subset of finger millet germplasm using geographical origin and data on 14 quantitative traits. *Genetic Resources and Crop Evolution* **53**:679-685.

Upadhyaya HD, NDRK Sarma, SK Singh, SK Varshney, VG Reddy, S Singh, SL Dwivedi, N Wanyera, COA Oduori, MA Mgonja, DB Kisandu, HK Parzies and CLL Gowda. 2010. Developing a mini-core collection in finger millet using multilocation data. Crop Science **50**:1924-1931.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Evaluation of High Mountain Bean Germplasm against Rust Disease (*Uromyces appendiculatus*) at Khumaltar, Lalitpur

Ajaya Karkee, Deepa Singh Shrestha and Suk Bahadur Gurung

ABSTRACT

Bean rust disease caused by *Uromyces appendiculatus* is the major yield limiting factors for bean around the world. Most effective way to manage bean rust is by the utilization of resistant cultivars. The aim of the study was to screen the high mountain bean genotypes against the rust disease. Twenty-eight bean genotypes from Nepal mountains, including Trishuli Ghiu Simee as standard check, were evaluated for the rust disease in the field and green house under Khumaltar (middle mountain) conditions in 2018. The field experiment was conducted under natural disease pressure and artificial inoculation was done in the greenhouse experiment. Disease scoring was done on 1-5 scale and area under disease progress curve (AUDPC) values were calculated. Four genotypes from Darchula (KA-017-04FB, KA-017-07FB, KA-017-06FB and KA-017-03FB) and two genotypes from Jumla (EP-015-15FB and DS-018-02FB) showed no rust symptoms under the field conditions. All genotypes showed rust when inoculated under greenhouse conditions. Genotypes EP-015-03FB and EP-015-02FB had higher AUDPC value under the field and higher rust scoring under the greenhouse conditions. The resistant landraces from this study can be utilized for breeding resistant varieties of beans which need further validation through molecular studies.

Keywords: Bean rust, diseases resistant, genotype screening, mountain

INTRODUCTION

Field bean (*Phaseolus vulgaris* L.), also known as Phaseolus bean (in Nepali - Simee, Rajma), is grown during summer in the mid and the high mountains of Nepal. It is nutrition rich and has unique taste, and good market value within Nepal (Joshi et al 2020a, Joshi et al 2020b). It is important cash generating crop for people of the high mountain like Jumla and Mustang. Beans are grown in sole cropping or in mixtures based on the market value and mixtures are exceptionally based on traditional knowledge (Joshi et al 2020a, Joshi et al 2018). The mixtures of landraces with different size and seed coat patterns are harvested and sold in the market as mixed beans (Shrestha et al 2011, Joshi et al 2020a) which fetches good price. Very high varietal diversity exists in beans in Nepal but only few varieties such as Trishuli Ghiu Simee and Chaumase Simee (four season bean) have been officially released and Mandir is registered for cultivation (Joshi et al 2017).

A high number of destructive pathogens attack and cause serious damage to the crop (Souza et al 2013). Among them is bean rust, incited by the fungus *Uromyces appendiculatus* F. Strauss 1833 (syn: *U. phaseoli* Pers.). The pathogen is an obligate, autoecious and macrocyclic fungus (Allen 1983, McMillan et al 2003) that possesses diverse races which are highly variable in virulence (Mmbaga et al 1996b, Araya et al 2004). This disease is distributed throughout the world and highly influenced by environmental factors such as temperature and humidity and host factors such as leaf age and causes major production problems in humid tropical and subtropical regions (Souza et al 2013). The disease can cause up to 100% yield loss depending upon earliness and severity of infection (Manandhar et al 2016). According to Lindgren et al (1995) everyone per cent increase in bean rust severity leads to a yield loss of approximately 19 kg/ha. The major mode of dissemination of bean rust is by wind, but other agents of dissemination include migratory birds, insects, water and sometimes through contaminated farm implements and infected plant debris (Liebenberg and Pretorius 2010). The factors that contribute to the distribution and prevalence of bean rust disease include altitude, ecological zones and human activities (Helfer 2014, Lin 2011).

Management of bean rust has relied primarily on three strategies: application of fungicides, host resistance, and various cultural practices, ie crop husbandry techniques (Mmbaga et al 2013). Although cultural practices are effective in reducing the amount of initial infection, the rate of rust infection increases and the high mobility of the rust spores often offset the initial benefits when environmental conditions are favorable. Chemical control has been a mainstay in intensive production areas where bean growers manage their crop for maximum yield and quality. However, the growing awareness of environmental degradation due to pesticides has raised concerns over chemical control strategy. With chemicals often too costly for farmers and cultural measures only partially effective, the use of host resistance as the primary method for managing bean rust has been attractive for bean producers (Mmbaga et al 1996a). Resistance to bean rust is controlled by a series of several genes that to date all are single and dominant (Kelly et al 1996). However, durability of disease resistance has often been short due to the use of single genes for resistance interacting with extremely high virulence diversity of the bean rust fungus (Mmbaga et al 1996b).

Among all management strategies, use of resistant cultivars is not only harmless to the environment but also economically sound strategy as compared to the others (Souza et al 2013). However, the wide variability of *U. appendiculatus* represents an obstacle to breeders aiming at the development of common bean cultivars with durable resistance to rust (Souza et al 2013). Screening of bean genotypes to rust resistance requires appropriate environmental conditions for disease development in the field so that the response of the test cultivars to the disease could be differentiated. The objective of this study was to identify the rust disease resistant/tolerant bean genotypes.

MATERIALS AND METHODS

Plant materials and site description

The materials used in this study consisted of a total of 28 bean landraces collected from the high mountain ecological zones of Nepal (**Table** 1). Released variety Trishuli Ghiu Simee was used as standard check.

Table1. List of bean landraces used in bean rust trial at Khumaltar, Lalitpur during 2018

Collection number	Local name/Variety	District	Latitude	Longitude	Altitude
KA-017-01FB	Batulo Simee	Darchula	29.80	80.65	2146
KA-017-02FB	Kaleji Chiribire Simee	Darchula	29.78	80.65	2146
KA-017-04FB	Ankhe Simee	Darchula	29.78	80.65	2146
KA-017-07FB	Temase Simee	Darchula	29.80	80.62	2146
KA-017-06FB	Kalo Simee	Darchula	29.80	80.62	2146
KA-017-03FB	Rato Chiribire Simee	Darchula	29.78	80.65	1536
EP-015-17FB	Julabi Sano Simee	Jumla	29.29	80.12	2968
EP-015-15FB	Kaleji Rato Simee	Jumla	29.29	80.12	2968
EP-015-12FB	Besare Lamcho Simee	Jumla	29.29	80.12	2968
EP-015-11FB	Kalo Chepto Simee	Jumla	29.29	80.12	2968
EP-015-03FB	Gulabi Thulo Male Simee	Jumla	29.29	80.12	2968
EP-015-09FB	Kalo Thulo Male Simee	Jumla	29.29	80.12	2968
EP-015-02FB	Khairo Batulo Simee	Jumla	29.29	80.12	2968
EP-015-04FB	Kalo Sano Male	Jumla	29.29	80.12	2968
EP-015-01FB	Kalo Masino Simee	Jumla	29.29	80.12	2968
DS-018-03FB	Simtane Simee	Jumla	29.29	80.12	2968
DS-018-02FB	Rato Siure Simee	Jumla	29.29	80.12	2968
DS-018-01FB	Seto Male Simee	Jumla	29.29	80.12	2968
DS-018-06FB	Kaleji Simee	Jumla	29.29	80.12	2968
DS-018-07FB	Kalo Masino Simee	Jumla	29.29	80.12	2968
DS-018-05FB	Khairo Masino Simee	Jumla	29.29	80.12	2968
DS-018-04FB	Khairo Simee	Jumla	29.29	80.12	2968
NGRC08503	Pahelno Simee	Dolakha	27.67	86.17	1920
NGRC08500	Dolakha Ghiu Simee	Dolakha	27.67	86.17	1920
NGRC05054	PB-0001	Jumla	29.23	82.26	2968
	Chaumase Ghiu Simee	Kathmandu			
	Rajma Utkarsha	Kathmandu			
	Trishuli Ghiu Simee	Kathmandu			

Experimental design and cultural practices

Experiments were conducted in a field at the National Agriculture Genetic Resource Centre (NAGRC), Khumaltar (experiment 1) and in a greenhouse of NAGRC in the same season (experiment 2).The research field of NARGC is located at an altitude of 1368 m, latitude of 027º40'N and longitude of 085º20'E (Genebank 2018). Soil type of the experimental blocks was black and loamy (Ghimire et al 2013).

Field experiment

Twenty-eight landraces of beans (**Table** 1) were used as treatments and the experiment was laid out in a randomized complete block design (RCBD) with three replications. Seeding was done on 29th April 2018. All agronomic and management practices were followed as per standard recommendations.

Greenhouse experiment

The same set of landraces of bean was used in the greenhouse and the experiment was laid out in a complete randomized design (CRD) with three replications. Each treatment was shown on a plastic pot (30cm × 30cm) and one experimental unit consisted of single plant with three replicates. Rust pustules were collected from the open field of bean at Khumaltar. The collected rust pustules were mixed with distilled water and sprayed equal volume of the spore suspension over the leaf of bean during evening at 30 days after sowing (DAS). High humid conditions were created by covering the pots with transparent polyethylene for overnight.

Disease assessment

In the greenhouse, rust scoring was done after 15 days of the inoculation on 0-5 scale given by Manandhar et al (2016) (**Table** 2).

Table 2. Bean rust scoring scale Manandhar et al (2016)

Scale	Plant parts affected
0	No disease
1	1-10% leaflet area with lesions
2	11-25% leaflet area with lesions
3	26-50% leaflet area with lesions and limited chlorosis
4	Over 50% or more of the leaflet area with lesions and extensive necrosis
5	Defoliation

In the field, four plants were chosen randomly from each plot and disease scoring was done at 87 DAS (July 24), 93 DAS (July 31), 100 DAS (Aug 7) and 107 DAS (Aug 14) on weekly interval after the appearance of the disease symptoms in the field. Diseases severity (DS %) was calculated from the scoring scale as:

$$DS\% = \left(\frac{\text{Sum of Numerical rating}}{\text{No. of plant examined} \times \text{Maximum grade}}\right) \times 100$$

Area under disease progress curve (AUDPC) was calculated from the disease severity (DS %) by the formula

$$AUDPC = \sum_{i-1}^{n} [(y_{i+1} + y)/2][x_{i+1} - x_i]$$

Where,

yi and yi+1 are the severity in the ith observation and (i+1)th observation
xi and xi+1 are the time (weeks in our study) in the ith and (i+1)th observation
and n is the total number of observations

Data analysis

Disease severity and AUDPC data were analyzed by Microsoft excel 2010 and Mstat-C (computer-based statistical software developed by the Crop and Soil Sciences, Department of Michigan State University, USA). Multiple mean comparisons between treatments were performed using LSD range test, where α = 0.05 and analysis of variance (ANOVA) was performed using General Linear Model. Mean separation of disease scoring data of greenhouse was done by Minitab version 17.

RESULTS

Field experiment

Area under disease progress curve (AUDPC) values of rust disease was found significantly different in different dates of disease scorings among bean genotypes (**Table** 3). Significantly highest AUDPC value was observed on EP-015-02FB genotypes and was at par with the check variety Trishuli Ghiu Simee. Similarly, KA-017-02FB, EP-015-09FB and DS-018-05FB possessed significantly lower AUDPC value than the other varieties but also not significantly different from the check variety Trishuli Ghiu Simee KA-017-04FB, KA-017-07FB, KA-017-06FB, KA-017-03FB, EP-015-15FB and DS-018-02FB were found disease free under the field conditions.

Table 3. Area under disease progress curve (AUDPC) of rust in bean genotypes, 2018, Khumaltar, Lalitpur

Genotype	AUDPC value		
	July 31	Aug 7	Aug 14
KA-017-01FB	63.5^{a}	164.1^{abcd}	263.2^{abcd}
KA-017-02FB	9.9^{bcd}	50.9^{ef}	103.6^{ef}
KA-017-04FB	0.0^{e}	0.0^{g}	0.0^{g}
KA-017-07FB	0.0^{e}	0.0^{g}	0.0^{g}
KA-017-06FB	0.0^{e}	0.0^{g}	0.0^{g}
KA-017-03FB	0.0^{e}	0.0^{g}	0.0^{g}
EP-015-17FB	37.9^{abc}	105.0^{abcd}	185.8^{abcdef}
EP-015-15FB	0.0^{e}	0.0^{g}	0.0^{g}
EP-015-12FB	30.2^{abc}	70.0^{def}	100.8^{ef}
EP-015-11FB	80.2^{a}	153.5^{abcd}	267.6^{abcd}
EP-015-03FB	124.6^{a}	250.3^{a}	361.6^{a}
EP-015-09FB	2.8^{de}	33.9^{f}	89.3^{f}
EP-015-02FB	102.2^{a}	224.9^{ab}	352.1^{ab}
EP-015-04FB	47.7^{abc}	104.3^{abcd}	136.9^{cdef}
EP-015-01EB	36.6^{abc}	78.3^{cdef}	135.5^{cdef}
NGRC05054	26.4^{abc}	104.3^{abcde}	198.0^{abcdef}
DS-018-03FB	57.8^{ab}	139.2^{abcd}	224.9^{abcde}
DS-018-02FB	0.0^{e}	0.0^{g}	0.0^{g}
DS-018-01FB	90.8^{a}	185.2^{abc}	301.9^{abc}
DS-018-06FB	50.8^{abc}	117.3^{abcde}	180.3^{abcdef}
DS-018-07FB	91.8^{a}	175.5^{abcd}	268.5^{abcd}
DS-018-05FB	9.0^{cd}	50.8^{ef}	96.8^{f}
DS-018-04FB	40.3^{abc}	100.8abcde	122.6^{def}
NGRC08503	40.0^{abc}	87.8^{bcdef}	155.5^{bcdef}
NGRC08500	59.7^{a}	132.4^{abcde}	221.1^{abcde}
Chaumase**Ghiu**Simee	51.5^{abc}	128.9^{abcde}	222.6^{abcde}
RajmaUtkarsha	31.9^{abc}	103.9^{abcde}	174.9^{abcdef}
Trishuli**Ghiu**Simee	37.9^{abc}	105.3^{abcde}	196.7^{abcdef}
LSD, 0.05	4.4	1.6	1.3
F test	*	**	***
CV, %	35.2	15.7	12.2

Greenhouse experiment

All beans genotypes showed rust symptoms under artificially inoculated conditions in the greenhouse and the score differed significantly among the tested genotypes (**Figure** 1). Nine genotypes KA-017-04FB, KA-017-07FB, KA-017-06FB, KA-017-03FB, EP-015-15FB, EP-015-04FB, EP-015-01FB, DS-018-02FB and DS-018-05FB showed significantly lower score than the check (3.5) but they values were at par with each other.

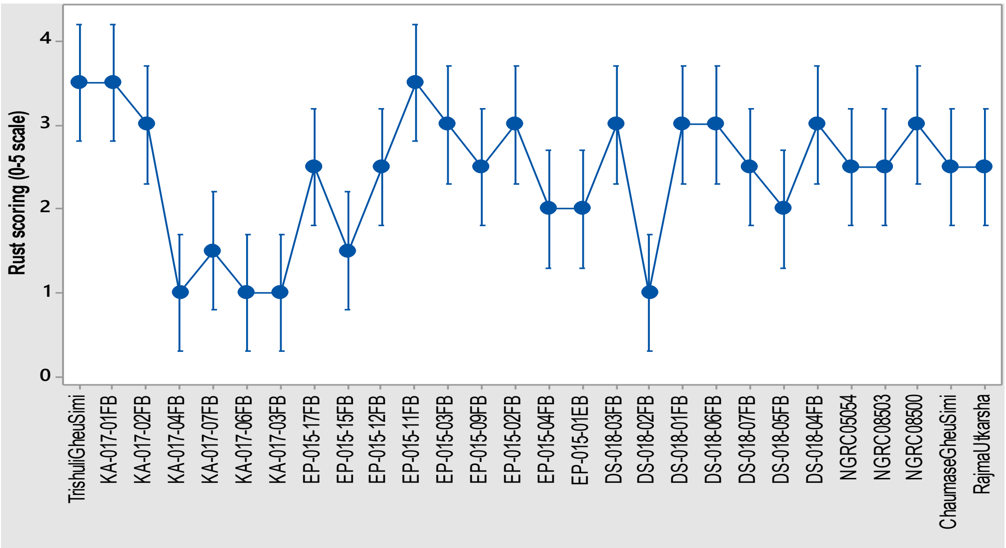

Figure 1. Rust disease score (0-5 scale) on bean genotypes under artificial inoculated conditions at greenhouse during 2018, Khumaltar, Lalitpur.

DISCUSSION

Six genotypes from Darchula, seventeen genotypes from Jumla, two genotypes from Dolakha, and one released and two registered varieties of bean were used in the experiments and these genotypes showed variable degree of susceptibility to the rust pathogen both in the field and greenhouse under Khumaltar conditions. Bean rust disease development in field depends on many factors, including susceptibility of the host genotype and the amount of secondary inoculums produced within a bean field (Mmbaga and Steadman 1992).

Rust disease symptoms on bean appeared after 10 days of inoculation in the greenhouse. Repeated disease cycles, which according to Schwartz et al (2004) may take 10-14 days under favourable conditions, were observed during this study also. .Four genotypes collected from Darchula (KA-017-04FB, KA-017-07FB, KA-017-06FB and KA-017-03FB), two genotypes collected from Jumla (EP-015-15FB and DS-018-02FB) showed immune to the disease in the field but none of the genotypes was immune when inoculated under the greenhouse conditions. It must be due to high inoculum pressure in the greenhouse. Twizeyimanna et al (2007) also stated that high disease pressure under artificial inoculated conditions could have masked the low to moderate levels of horizontal resistance.

The genotypes (KA-017-04FB, KA-017-07FB, KA-017-06FB, KA-017-03FB, EP-015-15FB and DS-018-02FB) showing resistant to the rust disease had significantly less AUDPC value in the field and significantly low disease score in the greenhouse.The rest of the test genotypes had significantly higher AUDPC value and score in the field and greenhouse, respectively, confirming their susceptibility to the rust disease.

CONCLUSIONS

Four genotypes from Darchula (KA-017-04FB, KA-017-07FB, KA-017-06FB and KA-017-03FB) and two genotypes from Jumla (EP-015-15FB and DS-018-02FB) showed no rust symptoms under the field conditions. Utilization of the bean germplasm identified as resistant to rust under middle mountain conditions in this study, should be further tested in Jumla and other high mountain districts for validation and can be used for yield trial and in breeding program.

ACKNOWLEDGEMENTS

Authors would like to acknowledge for the encouragement from BK Joshi, KH Ghimire, and technical/support from NAGRC; and D Gauchan from Bioversity International for implementing the research activity.

REFERENCES

Allen DJ. 1983. The Pathology of Tropical Food Legumes: Disease Resistance in Crop Improvement. New York, USA: John Wiley and Sons.

Araya CM, AT lleyne, JR Steadman, KM Eskridge and DP Coyne. 2004. Phenotypic and genotypic characterization of *Uromycesappendiculatus* from *Phaseolus vulgaris* in the Americas. Plant Disease **88**:830-836.

Genebank. 2018. Annual Report 2074/75 (2017/18). National Agriculture Genetic Resources Centre, NARC (KH Ghimire, D Singh and A Karkee eds.) Khumaltar, Lalitpur, Nepal.

Ghimire KH, M Bhattarai, BK Joshi and MR Bhatta. 2013. Agro-morphological characterization of Nepalese rice (*Oryza sativa* L.) landraces. **In**: Proceedings of the 27th National Summer Crop Workshop, Nepal Agricultural Research Council, Sinhadarbar Plaza, Kathmandu.

Helfer S. 2014. Rust fungi and global change. New Phytopathologist **201**(3):770-780.

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages. Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal, and BR Sthapit. 2017. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, NARC, and Bioversity International, Nepal. https://www.bioversityinternational.org/fileadmin/user_upload/Released_and_promising_crop_varieties.pdf

Joshi BK, RC Prasad, R Gurung, S Gautam, A Subedi, AR Adhkari, A Karkee and D Gauchan. 2020a. Tradition of Mixing Bean Landraces: Diversity Rich Solution for Secured Quality Harvest and Conservation in Mountain Agriculture. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020b. Nutritionally Unique Native Crop Landraces from Mountain Nepal for Geographical Indication Right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Kelly JD, JR Stavely, and PN Miklas. 1996. Proposed symbols for rust resistance genes. Annual Report of Bean Improvement Cooperatives **39**:25-31.

Lin BB. 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. BioScience **61**(3):183-193.

Lindgren DT, KM Escridge, JR Steadman and DM Schaaf. 1995. A model for dry bean yield loss due to rust. Horticulture Technology **5**:35-37.

Manandhar HK, RD Timila, S Sharma, S Joshi, S Manandhar, SB Gurung, S Sthapit, E Palikhey, A Pandey, BK Joshi, G Manandhar, D Gauchan, DI Jarvis and BR Sthapit. 2016. A Field Guide for Identification and Scoring Methods of Diseases in the Mountain Crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

McMillan MS, HF Schwartz HF and KLOtto. 2003. Sexual stage development of *Uromycesappendiculatus* and its potential use for disease resistance screening of *Phaseolus vulgaris*. Plant Disease **87**:1133-8.

Mmbaga MT and JR Steadman. 1992. Nonspecific resistance to rust in pubescent and glabrous common bean genotypes. Phytopathology **82**:1283-1287.

Mmbaga MT, JR Steadman and JR Stavely. 1996a. The use of host resistance in disease management of rust in common bean. Integrated Pest Management Reviews **1**:191-200.

Mmbaga MT, JR Steadman and KM Eskridge. 1996b. Virulence patterns of *Uromyces appendiculatus* from different geographical areas and implications for finding durable resistance to rust of common bean. Journal of Phytopathology **144**(12):533-541.

Schwartz HF, JR Steadman and DT Lindgren. 2004. Rust of Dry Beans. Fort Collins, CO, USA: Colorado State University: Cooperative Extension Report No. **2**·936.

Shrestha R, RN Neupane and NP Adhikari. 2011. Status and future prospects of pulses in Nepal. Paper presented at Regional Workshop on Pulse Production held at Nepal Agricultural Research Council (NARC), Kathmandu, Nepal from 24-25 October 2011.

Souza TLPO, FG Faleiro, SN Dessaune, TJ Paula-Junior, MA Moreira and EG de Barros. 2013. Breeding for common bean (*Phaseolus vulgaris* L.) rust resistance in Brazil. Tropical Plant Pathology **38**(5):361-374.

Twizeyimanna M, PS Ojiambo, T Ikotun, C Paul, GL Hartman and RB Upadhyay. 2007. Comparisons of field, greenhouse, and detached-leaf evaluations of soybean germplasm for resistance to *Phakopsora pachyrhizi*, Plant Disease **91**:1161-1169.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Jumli Maarsee Rice Evolved in Jumla, Nepal: Nature's Choices for High Mountains with Nutrition Dense Landrace

Bal Krishna Joshi, Pravin Ojha, Devendra Gauchan and Pashupati Chaudhary

ABSTRACT

Jumli Maarsee is a native japonica rice landrace cultivated since ancient time in the highest altitude in the world at Chhumchaur (3050 msl), Jumla in Nepal Himalayas. Some people believe that this rice was introduced from Kashmir, India by a Hindu Saint, *Chandannaath Baba*. Recent interview with a local priest (Pujaari) of Chandannaath temple and our field studies confirm that this rice had been evolved in Jumla since *Chandannaath Baba* domesticated it from the wild rice found around the bank of Tila river in Jumla. Its name and high level of intra landrace diversity and indigenous rice culture found in Jumla also support our view. Jumli Maarsee rice might have evolved or originated in Jumla as many native rice landraces evolved in different locations in Nepal. Jumla is the original place for this rice and therefore, it has very unique traits owing its unique ecological condition, and its cold genes have been globally used. Jumli Maarsee is also nutrition-dense and possesses a higher amount of polyphenol and antioxidant, making it a nutritional and healthy diet for humans. Furthermore, molecular, archeological and anthropological studies are needed to verify its origin and uniqueness.

Keywords: Evolution, intra landrace diversity, Jumli Maarsee rice, nutrition rich, unique trait, wild rice

INTRODUCTION

Nepal is one of the centers of origin for rice. About more than 2000 landraces of rice were available across the country and Jumli Maarsee (also spelled Jumli Marshi) is one of them (Mallik 1981/82, Upadhyay and Joshi 2003, Joshi 2004). Globally Jumli Maarsee rice is recognized as the most cold-tolerant landrace grown in the highest altitude (3050 m) in the world (Mallik 1981/82, Upadhyay and Joshi 2003, Acharya 2019, Lindlöf et al 2015). More than 50 countries have used Jumli Maarsee rice in research, breeding, and production (Joshi et al 2017). There is a belief that Jumli Maarsee absorbs ghee (butter-fat) and milk easily and makes rice pudding smooth and tasty (Acharya 2019). However, Jumli Maarsee is at risk of loss from Jumla mainly because of converting rice-growing land to buildings and other purposes, switching of farmers to other businesses and leaving agriculture land fallow. This is high altitude rice and its origin as well as nutritional status has not been documented adequately.

We made a several field visits to Jumla in the last five years and made interview with the local farmers, key informants including the priest of Chandannath temple at Khalanga, Jumla in 2018 and discussed potential origin, cultivation, and use of Jumli Maarsee landrace. Nutrient contents of this landrace along with other varieties were assessed in Food Research Division, NARC, Khumaltar, Nepal in the late 2019. This paper describes origin, cultivation and nutrition content of Jumli Maarsee rice landrace based on the literature review, field interviews with local farmers and key informants, and nutrition analysis along with our experiences of working in this crop over the last 20 years.

DIVERSITY AND ORIGIN

A detailed sample survey of farm households in Talium, Jumla in 1998 by the Global In-situ Agrobiodiversity Conservation Project listed 20 variants of Maarsee landraces from Jumla (Rana et al 2000). Based on farmers' names, Jumli Maarsee includes Kaali Maarsee, Raato Maarsee, Seto Maarsee, Daarime Maarsee, Mehele Maarsee, etc. Kali maarsee is believed to be the original domesticated one (Chaulagain and Saund 2017). Major variation is observed in seed and plant color. Intra landrace diversity can be seen clearly and some genotypes have awn and some without awn. It grows under wet lowland (Sim), stream irrigated (Kholapani), rainfed lowland and upland systems. Cold tolerant Maarsee rice landraces are also available in other areas but they differ from Jumli Maarsee (Acharya 2019) on morphotypes and quality. Major domains for the production of Jumli Maarsee are Tila and Sinja valleys in Jumla. The Sinja valley is also a place where the Nepali language originated and it is the home for many other crop species (Acharya 2019). This is also an UNESCO World Heritage site.

Some of the farmers and key informants of Jumla believe that Jumli Maarsee was introduced to Jumla from Jammu and Kashmir, India (Rana et al 2000, Acharya 2019). But our interview with the priest of Chandannath temple and some key informants along with field observations revealed that this landrace was originated in Jumla valley itself. The well-known Hindu Saint, *Chandannath Baba* domesticated this landrace from the wild rice (locally called *naabo*) which was found around the Tila river valley in Jumla. Originally, the valley was a lake, and wild rice was found in the periphery of the lake, which was domesticated for its cultivation. It was understood that the *Chandannath Baba* drained the water from the lake and taught his disciples to domesticate the wild rice (naavo) for local food production. Evidence of lake and rice domestication in Jumla was also supported by some writings (Chaulagain and Saund 2017, Joshi 2018, Acharya 2019). Main justifications for attesting Jumla as the origin of Jumli Maarsee are:

- It is considered commonly as native and indigenous to Jumla;
- It does not represent just one type as seen in other introduced varieties and has different variants which indicate that many diverse forms of genotypes got evolved in Jumla due to continued cultivation;
- Cultivation practices of Jumli Maarsee are unique linked with indigenous culture and production system and these practices were developed in Jumla over generations, which do not match with other area's production system;
- Name itself indicates that this rice is from Jumla;
- It has a long socio-economical history with Jumli farmers, even linked with the royal family and Rana rules of Kathmandu valley, Nepal;
- The climate in Jumla is colder than Kashmir and cold tolerant property of this landrace is also unique and such landrace by this name is not available in Kashmir;
- Cultivation practices and the name itself were not introduced from Kashmir and other areas;
- Government of Nepal issued official stamp of Jumli Maarsee rice in 2004 as a recognition for its unique native landrace of Nepal; and
- Priest of Chandannaath temple in Khalanga, Jumla (district headquarter) also believed that Jumli Maarsee is originated in Jumla district.

Chhumchaur (3050 msl), Jumla

Interview about Jumli Marsee origin at Chandanath Temple, Jumla, 2018

Chhumchaur, Jumla, the highest altitude rice growing area. Photo credit: SP Vista

Study team relishing the taste of original Jumli Maarsee rice in Khalanga, Jumla, 2018

Jumli maarsee rice landrace

Chhumchaur field with farmers. Photo credit: RB. Bhujel

Figure 1. Origin place of Jumli Maarsee rice in Jumla, Jumli farmers and priest of Chandannaath temple.

UNIQUENESS AND USES

Major unique traits of Jumli Maarsee are early maturity, colored grain, sticky, cold tolerant and tasty (Lindlöf et al 2015, Bajracharya et al 2006, Acharya 2019, Joshi et al 2014). These traits have been evolved after a long interaction of this landrace with nature and being maintained through continued cultivation in its original place. Jumli Maarsee is a staple food crop in Jumla district and its demand in other areas is very high mainly because of good taste and healthy diet. It has also medicinal value (Acharya 2019).

NUTRIENT CONTENTS

Nutrient contents of Jumli Maarsee rice along with other three popular landraces of Nepal and one modern variety are given in **Table** 1. The findings of the nutrient analysis revealed that Jumli Maarsee has higher amount of protein, micronutrients and antioxidants as compared to popular native rice varieties grown in other hill and mountain regions of Nepal such as Boraang from Rasuwa, Saali from Baitadi and Hansaraj from Bajhang districts, in the far western mountains. The amount of protein, polyphenol, flavonoid, and antioxidant are also higher in Jumli Marshee compared to other varieties. Mineral content (iron, calcium, and phosphorous) is also higher in Jumli Maarsee rice compared to Khumal-4, one of popular rice variety in the mid-hill region. Antioxidants help protect cells against free radicals. Similarly, polyphenol and flavonoid keep cells active and young protecting cells from damage, and also increase the anti-oxidant property (Puravankara et al 2000). This rice therefore has significant role in keeping people healthy in high altitude areas, where, high solar intensity can damage cells. High polyphenols and antioxidant might be the results of continued interaction of Jumli Maarsee with high altitude climate over a long period of time (see Joshi et al 2014 for climate in Jumla). Low carbohydrate and high fiber in Jumli Maarsee prove its suitability for the obese and diabetic patient (Venn and Mann 2004), however, carbohydrate profile and the glycemic index needs to be assessed to verify the statement.

Table 1. Nutrient contents of Jumli Maarsee rice and other native landraces and modern rice variety

Nutrient	Jumli Maarsee	Boraang	Saali	Hansaraaj	Khumal-4*
Moisture (%)	12.24	12.98	12.65	12.11	9.92
Crude fat (%)	2.20	2.04	2.48	2.28	1.52
Total ash (%)	1.23	1.10	1.07	1.34	1.08
Crude protein (%)	9.86	8.35	8.53	7.52	5.38
Crude fiber (%)	2.01	1.89	2.27	2.89	0.89
Carbohydrate (%)	72.47	73.63	73.00	73.88	81.21
Iron (mg/100g)	0.57	1.60	1.06	0.40	0.22
Phosphorous (mg/100g)	57.54	59.98	51.92	52.53	12.39
Calcium (mg/100g)	66.70	106.89	73.79	86.25	40.53
Polyphenol (mg GAE/100g)	204.83	82.66	73.76	70.41	
Flavonoid (mg GAE/100g)	83.32	57.10	55.71	46.80	
Antioxidant activity (% shown by about 60 mg/ml extract)	75.66	22.07	17.20	17.46	

** Modern variety. Source: Food Research Division, NARC, Khumaltar; Joshi et al 2020.*

CONCLUSION

Jumli Maarsee rice is highly valued in Nepal because of its unique adaptation, taste and cultural values. Intra landrace diversity, unique indigenous rice culture and production system along with many socio-economical associations with Jumli Maarsee rice indicated the very long history of cultivation of Jumli Maarsee rice in Jumla district. Jumla might be the potential origin of this landrace, which is supported by the globally important unique cold tolerant and nutrition-dense traits in this landrace, and different morpho and genotypes within landraces. It is nutrition-rich with high amount of polyphenols and antioxidant. Furthermore, molecular, archeological and anthropological studies are needed to verify its origin and uniqueness. Carbohydrate profile, glycemic index, amino acid sequence, and polyphenol constituents need to be assessed to recognize the nutritional distinctiveness.

REFERENCES

Acharya PP. 2019. Jumli Maarsee Dhaan. Sambridhi Media Bizypan Agency, Kathmandu (in Nepali language).

Bajracharya J, KA Steele, DI Jarvis, B Sthapit and JR Witcombe. 2006. Rice landrace diversity in Nepal: Variability of agro-morphological traits and SSR markers in landraces from a high-altitude site. Field Crops Research **95**:327–335.

Chaulagain BP and NB Saund. 2017. Introduction of rice and its cultivation practices in Jumla. **In**: Rice Science and Technology in Nepal (MN Paudel, DR Bhandari, MP Khanal, BK Joshi, P Acharya and KH Ghimire, eds). Crop Development Directorate (CDD), Hariharbhawan and Agronomy Society of Nepal (ASoN), Khumaltar; **pp**. 266-271.

Joshi BK. 2004. Rice gene pool for mid and high hills and its conservation in Nepal. **In**: Agricultural Research for Enhancing Livelihood of Nepalese People (BK Joshi, SL Joshi and KP Paudyal, eds). Proceedings of 2nd SAS-N Convention, 30 July - 1 Aug 2003, Kathmandu; **pp**.252-264. http://sites.google.com/site/jafgaubase/publication/book-editorial-1,

Joshi BK, F Hay, S Sapkota and K Ebana. 2017. Nepalese rice around the world. **In**: Rice Science and Technology in Nepal. Crop Development Directorate (CDD), Hariharbhawan; **pp**. 221-240. http://cddnepal.gov.np/downloadfile/Rice_science_and_technology_1512106674.pdf

Joshi BK, ML Vaidya, HK Upreti, DR Sharma, CB Rana, PM Mahat, SR Gupta and S Bista. 2014. Rice and buckwheat genetic resources in Karnali zone. Agriculture Development Journal **10**:1-22.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi TN. 2018. Saving of popular Jumli Maarsee rice (Nepali version), Kantipur daily (3 Srawan 2075 BS). https://www.kantipurdaily.com/bibidha/2018/07/19/153198215847366811.html?fbclid=IwAR15MwzTNYtx0RXrEpl7hsLInVxelrUVoqJBJpgjZGeZAagGxOIlFmvf4_w

Lindlöf A, A Chawade, P Sikora and O Olsson. 2015. Comparative transcriptomics of Sijung and Jumli Maarsee rice during early chilling stress imply multiple protective mechanisms. PLoS ONE 10(5): e0125385. **DOI**: 10.1371/journal.pone.0125385

Mallik RN. 1981/82. Rice in Nepal. Kala Prakanshan, Kathmandu.

Puravankara D, V Boghra and RS Sharma. 2000. Effect of antioxidant principles isolated from mango (*Mangifera indica* L) seed kernels on oxidative stability of buffalo ghee (butter-fat). J. Science of Food & Agriculture **80**:522-526.

Rana RB, CL Paudel, PR Tiwari, D Gauchan, A Subedi, BR Sthapit, MP Upadhyay and DI Jarvis. 2000. In situ crop conservation: Findings of agro-ecological, crop-diversity and socio-economic baseline survey of Talium ecosite, Jumla, Nepal, NP working Paper No 3/2000. NARC/LIBIRD, IPGRI.

Upadhyay MP and BK Joshi. 2003. Plant Genetic Resources in SAARC Countries: Their Conservation and Management: Nepal Chapter. SAARC Agriculture Information Center; **pp**. 297-422. http://www.elibrary.icrisat.org/SATELib_files/SATELibNewsV4I3Mar2007.htm#NAB

Venn BJ, and JI Mann. 2004. Cereal grains, legumes and diabetes. European Journal of Clinical Nutrition **58**:1443-1461.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Advancement, Simplification and Piloting of Electrical Proso Millet De-husker (*Chino Kutak*) for the Mountain Farmers

Ganga Ram Bhandari, Devendra Gauchan, Bharat Bhandari, Bal Krishna Joshi and Saroj Panta

ABSTRACT

The proso millet (*Panicum miliaceum* L.) is a minor cereal crop commonly cultivated in rainfed marginal lands in upland slopes and terraces particularly in the mid and far western mountain region of Nepal. It is a potential crop for ensuring food and nutrition security and conservation of local crop biodiversity in the high mountain region. Traditionally proso millet (locally as *Chino*) is processed manually on mortar using muscular power by women. However, de-husking (pearling) of proso millet is very tedious job. Until recently, appropriate de-husking machines for proso millet were also not available in the country. The traditional method of processing takes 1 hour to dehusk 2 - 3 kg of proso millet for two women and cause lots of physical exertion to them. Therefore, GEF UNEP Local Crop Project in collaboration with Agricultural Engineering Division of NARC initiated program in 2017 to design, fabricate and test electric proso millet de-husking machine (called *Chino Kutak*) that is safe and economical in operation for the use of the local farmers of remote Himalayan region. The Model-1 designed, fabricated and piloted at Humla (Nalla village, Chhipra, Kharpunath Rural Municipality) in 2018, was improved version of finger millet processing machine. Due to the lack of scientific research lab facility our design and development of the proso millet processing machines was mainly based on the experiential knowledge (trial and error method). The Model-2, based on the centrifugal type working on impact principle was developed in January 2020. The Model-2 was very much successful for all varieties of proso millet and higher capacity up to 52.5 kg/hr. It is equally applicable to foxtail millet. This paper aims to outline the process and results of fabrication, improvement and piloting of proso millet processing system targeting small holder farmers in the western high mountains (Karnali Province) of Nepal.

Keywords: Abrasion, centrifugal, chino kutak, de-husking, drudgery, impact

INTRODUCTION

The proso millet (*Panicum miliaceum* L.) commonly known as *Chino* is a cereal crop cultivated as a grain crop in the Himalayas up to the altitude of 3500 meter. In Nepal, it is cultivated in marginal lands in the temperate region that is further North than any other millets are grown. Proso millet is a staple food crop and, cultivated as main cereals in the mountain regions of mid and far western Nepal (Joshi et al 2019). Proso millet is an erect annual grass up to 145-155 cm tall, usually free-tillering and tufted, with a rather shallow root system. Its productivity in Nepal is 60-70 kg/ropani (500 m^2) (Parajuli et al 2017). The grains are very small and oval in shape up to 3 mm long x 2 mm width, smooth. Seed color is wide ranging from white, cream, yellow, orange, red, and black through to brown. It is completely gluten-free and is packed with a variety of essential minerals, potassium in particular, which contributes to improve nervous system of health (Joshi et al 2020). The important popular local varieties of proso millet in Humla are black, red, milky and hardy varieties often locally named *Askalo Chino, Rato Chino, Dudhe Chino, Haande Chino* in Nepali language (Joshi and Ghimire 2015, Rawat et al 2019).

The removal of the husk layer thus becomes the primary task of processing of these grains for obtaining edible grain (naked grain) and for further processing of grains for consumption. Once removed, we get the proso millet ready to cook. Proso millet is consumed as cooked proso millet (like rice), pudding, porridge and can be eaten after beaten and milling as flour. Proso millet seeds are enclosed in the hulls, and difficult to remove by conventional milling processes. The de-husking of proso millet is very tedious and time-consuming work which is generally done by women farmers. However, appropriate de-husking machines are not available. Traditionally in the rural areas of Nepal, proso millet is de-husked (removal of outer coat of seed) in mortar and pestle (*Okhal, made up of stone and wood)* by using muscular power. The power levels that can be produced by an average healthy athlete is 75 W maximum (Modak and Bapat 1994). The major challenges in processing proso millet are: i) the small size with irregular shape of grain, ii) variations in the raw materials due to variation in varieties across production regions, ii) low shelf life of the processed grains and grits due to pest infestation and rancidity, and iv) hard, slippery outer coat of seed (husk) than found in other millets (DHAN Foundation 2019).

The field study in Chhipra, Humla in 2019 revealed that the traditional method of manual processing takes 1 hour to de-husk 2 to 3 kg of proso millet for two women (Bhandari et al 2020). They can de-husk only 20-30 kg in a day by two women and cause lots of physical exertion to them. Considering the strong need of the processing machine for the proso millet, the Local Crop Project in Nepal has studied the problem, designed and piloted electric proso millet processing machine (de-husker, called *Chino Kutak*) in the project site in Humla. At first, we studied and tried different de-husking/dehulling technologies namely; i) emery stone mill working on abrasion principle which was under research at Agricultural Engineering Division (AED), ii) rubber roller mill working on abrasion principle, and iii) centrifugal type working on impact principle. The first model (Model-1) designed, fabricated and piloted at Humla (Chhipra village, Kharpunath Rural Municipality) in 2018 was the improvised version of finger millet processing machine. Due to the lack of scientific research lab facility, our first design and development of the proso millet processing machines was based mainly on the experiential knowledge (trial and error method), the second model (Model-2) was based on the centrifugal type working on impact principle. This paper aims to outline the process and results of fabrication, improvement and piloting of proso millet processing system targeting smallholder farmers in the western high mountains (Karnali Province) of Nepal. The paper also presents experiences and lessons learned in the development and field piloting of model proso millet dehusker and the successful designing the improved version of Model-2 dehusker suited to all types of proso millet varieties including foxtail millet.

MATERIALS AND METHODS

General methods and process

Project developed programs for designing and developing appropriate machine for processing, field testing and feedback collections (**Figure** 1). To simplify the processing of proso millet, some bio-physical properties were studied at Agricultural Engineering Division (AED), NARC, Khumaltar. The piloting site was Humla, one of the Local Crop Project sites. The Model-1 machine was designed and fabricated at Agricultural Engineering Division with the financial support and facilitation of GEF UNEP Local Crop Project (LCP) in the year 2017. The project was successful in designing, fabrication and testing electric proso millet machine locally named as *Chino Kutak* Model-1 in September 2018 (Bhandari et al 2020). After testing of machine at AED, field performance evaluation and demonstration were carried out in Kharpunath Rural Municipality-4 at Nalla village (Chhipra) in Humla district, Nepal. To overcome the limitations of Model-1, the Model-2 was developed. The Model-2 machine was also designed and fabricated at AED with the financial support and facilitation of the LCP. The project was successful in designing, fabrication and testing electric proso millet machine locally named as *Chino Kutak* Model-2 in January 2020. The machine was tested at AED for different moisture contents and feed rates of proso millet and foxtail millet, too.

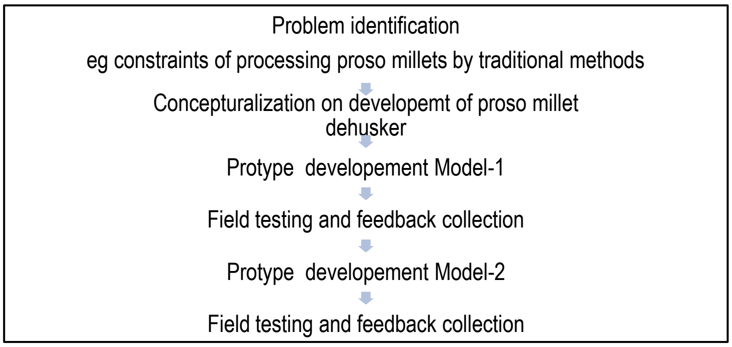

Figure 1. Process of research to design and simplify the processing machine for proso millet.

Machine fabrication and assembly

First principle of dehusking, mechanical components and materials required were conceptualized through literature review and past experience of designing finger millet and other electric threshers for other grain crops. After getting failure with Emery stone mill working on abrasion principle which was under research at AED, the Model-1 was designed working on abrasion principle and Model-2 was designed as centrifugal type working on impact principle. The first model designed and fabricated was improvised version of finger millet processing machine. The Model-1 machine has the following units – feeding hopper, de-husking drum and separating unit.

The Model-2 machine has feeding hopper, double shell de-husking drum and grain and husk outlet unit. With the application of appropriate processes, resources and tool, the proso millet de-husking machine was fabricated by selecting suitable materials for each component. After making the components, it was assembled as per our design.

Testing

First machine was tested for the de-husking of proso millet at AED. Moisture content of proso millet before dehusking was measured using digital moisture meter. Grain was sun-dried the day before the dehusking. Treatment with calcium hydroxide and with high moisture content was also done. For field performance evaluation, Model-1 machine was transported by road and air flight to Humla and tested in Nalla village of Kharpunath Rural Municipality-4. The prototype was tested for the evaluation of its overall performance in terms of productivity, efficiency and capacity. Conclusions were drawn based on the results of the field performance test of the prototype and farmer's reactions, based on which improvements were made and recommendations were given. Model-2 was tested at AED in the presence of locals from Humla. It was tested for hard red chino and foxtail millet, also. The following indices were used to evaluate the performance of the machine.

$$\text{Dehusking efficiency } \% = \frac{A}{B} \times 100$$

$$\text{Broken } \% = \frac{D}{A} \times 100$$

$$\text{Head grain yield } \% = \frac{C}{A} \times 100$$

$$\text{Milling efficiency } \% = \frac{E \times F}{100}$$

Where,

A - Weight of milled grains (head grain and broken grain) (g)
B - Weight of grains fed to the machine (g)
C - Weight of head grains (g) (dehusked grain)
D - Weight of broken grains (g)
E - Dehusking efficiency
F - Head grain yield

The performance evaluation of Model-1 is carried out for different varieties, moisture content, and application of 2% lime water with following treatments.

T-1: Mixed type chino at moisture content 11.4%
T-2: Mixed type chino with application of 2% lime water for two hours, sun drying and dehusking at moisture content 14%
T-3: Dudhe chino at moisture content 10.4%
T-4: Dudhe chino at moisture content 12.4%

The performance evaluation of Model-2 is carried out for different varieties, moisture content and water treatment.

T-1: Mixed type chino at moisture content 11.4%
T-2: Rato chino with water treatment for 2 hours, sun drying and dehusking at moisture content of 14%
T-3: Rato chino at moisture content 10.4%
T-4: Rato chino at moisture content 12.4%

Machine design and fabrication

Major components in model-1

Power unit: The de-husker was operated by single phase electrical motor. A motor power of 1.5 hp was assumed for power requirement. Throughout the design of all the components, it is taken as the input power to the machine and considers all frictional losses to be negligible. Normally, a 1.5 hp motor has a speed of 1420 rpm (revolution per minute).

Hopper: Hopper is placed at the top of machine and made up of MS sheet metal. Feeding unit is made in such a way that grain is fed into threshing unit from throughout the length of threshing cylinder. Flow control rate or feed rate control mechanism is provided just below the hopper.

De-husking drum: This unit consists of rotating threshing cylinder on a shaft driven by electric motor. It is made of cast iron and is housed inside the threshing chamber. Numbers of stoppers are provided on the periphery as well as on the body of the dehusking drum. Stoppers on the rotating drum are made of general flat belt material. The speed of dehusking drum shaft is maintained at 460 rpm with the arrangement of proper belt-pulley transmission ratio. At the bottom of the de-husking drum, a screen with circular hole is provided through which mixture of threshed grain with husk get out. Dehusking drum cover is made up of MS sheet metal.

Separation unit: This unit consists of two screens with round hole of different sizes. It is shaken by the power from the electric motor. The speed of shaking shaft is maintained 720 rpm. Oversized portion goes out from first spout, material passed from top screen and retained on second are goes out from second spout and those which passes from second screen goes out from third spout outlet. Screens sets have been provided with 30 degree slope.

Component design: To remove the husk from the grain, one can use two forces – impact or shear. A stone grinding mill, manual or motor powered employs the shear force while manual pounding or centrifugal hulling machines use the impact force.

Power required to combing off husk from grains: The power required to thresh grains from the millet panicles is expressed as: $P = T \times \omega$ Power,

$$P = T\,.\omega = T \times 2\pi N/60 \text{ watts}$$

Where,

P = is the power required (watts)
T = torque of the drum (nm)
ω = angular velocity (rad/s)
N = speed of the threshing drum (rpm)
F = the impact force required to thresh millet
r = the distance of point of force application from axis of rotation (m)

The torque resulting from individual force is given by: $T = F \times r$
Total torque (T) on the drum was calculated as follows: $T = T_r \times K_b$
where, K_b is the number of beaters/stopper on the drum

Dimension and mechanical features of the machine:

Total height of machine = 116 cm
Diameter of drum = 36 cm
RPM of electrical motor of 1.5 hp = 1420
RPM of dehusking drum = 460
RPM of shaking screen shaft = 720
Slope of separation screen = 30 degree
Number of separation screen used = 2
Number of output collection = 3

Figure 2. Proso millet De-husker Model-1.

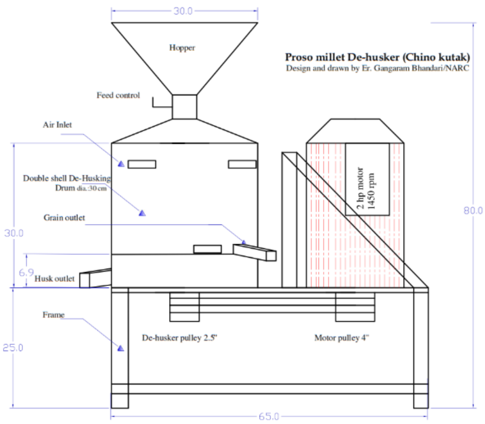

Figure 3. Centrifugal type Proso millet De-husker Model-2.

Major components in model-2

Power unit: The de-husker was operated by single phase 2 hp, 1540 rpm electrical motor. Throughout the design of all the components, it is taken as the input power to the machine and considers all frictional losses to be negligible.

Hopper: Hopper is placed at the top of machine and made up of MS sheet metal. Feeding unit is made in such a way that grain is fed into top rotating drum and made to spread all direction. Flow control rate or feed rate control mechanism is provided just below the hopper.

De-husking drum: This unit consists of double shell drum; the inner rotating rubber cylinder on a shaft driven by electric motor. Inner and outer shell is separated by metallic screen which separates the husk and provide the impact base for grains. Outer shell is covered by MS sheet. Numbers of stoppers are provided on the body of the rotating rubber cylinder. The rotating rubber cylinder rotating at rpm of 2300 cerates the centrifugal force to the feed grain and resulting impact on the wall (metallic screen) cases the de-husking. At the bottom of the rotating cylinder the de-husked grain outlet was made and in the outer shell a husk outlet was made at the bottom of machine. At least three air inlet slots are made on the body of machine.

Dimension and mechanical features of machine:
Total height of machine = 80 cm; Length = 65 cm (including motor frame); Width = 30 cm;
Diameter of drum = 30 cm; RPM of electrical motor of 2hp = 1450; RPM of rotating rubber cylinder = 2300

Machine testing

For testing, weighted samples of three varieties of proso millet; dudhe chino, rato chino and mixed types were evaluated at AED and field test and acceptance test were carried out in Nalla village (Chhipra) of Humla on November 23, 2018. Grains of different varieties of proso millet were separately placed in the hopper and then slowly the feed control mechanism was opened allowing the grains to pass into the threshing cylinder of threshing drum unit. Then after, the final output was collected from the outlets/spouts and weighted. Proso millet grain passes through the de-husking drum where it is de-husked, de-husked mixture of threshed, unthreshed and broken grain and husk came out of screen provided at the bottom of dehusking drum. The tests were conducted with the variations in speed ratio, moisture and number of re-feeding. The dehusking capacity, dehusking efficiency and grain percentage were calculated. The observations on the crop feed amount, time, moisture content, broken grain percentage and various efficiencies are presented in **Table** 1.

Table 1. Effects of variety and moisture contents and processing method on proso millet de-husker Model-1

Dehusking methods	Dehusking capacity (kg/hr)	Dehusking efficiency (%)	Head grain yield (%)	Broken yield (%)	Milling efficiency (%)
T1	25	81	70	30	56.70
T2	38	85	60	40	51.00
T3	35	82	72	28	59.00
T4	36	84	75	25	63.00
Mean	33.5	83	69.25	30.75	57.42

Picture 1. Dehusking by traditional method, testing at Agriculture Engineering Dividion, Khumaltar, dehusked grain, farmer participation during field testing in Nalla village, Humla.

Model-2 was tested at AED in the presence of locals from Humla district. Mixed type Chino, Rato Chino at different moisture contents and treatments were separately carried out. The observations on the crop feed amount, time, moisture content, broken grain percentage and various efficiencies are presented in **Table** 2.

Table 2. Effects of variety and moisture contents and processing method on proso millet de-husker Model-2

Dehusking method	Dehusking capacity (kg/hr)	Dehusking efficiency (%)	Head grain yield (%)	Broken yield (%)	Milling efficiency (%)
T1	55	88	70	30	61.60
T2	60	90	80	20	72.00
T3	45	86	70	30	60.20
T4	50	89	77	23	68.53
Mean	52.5	92	74.25	25.75	65.58

Picture 2. Testing of Model-2 in presence of locals from Humla.

RESULTS

Milling efficiency (%)

Table 1 and **Table** 2 depict the different effects of processing methods and condition on the performance of de-husker. Milling efficiency was very low for lime water-treated proso millet. Milling efficiency was found the highest for water-treated proso millet and shows the quite satisfactory resultant moisture content 12.4% and poor result at low moisture content level.

Dehusking capacity (kg/hr)

Dehusking capacity for de-husker in treatment T2 showed the highest. De-husker had low dehusking capacity at low moisture content. On an average, Model-1 has dehusking capacity more than 33.5 kg per hour whereas the Model-2 has 52.5 kg/hr.

Dehusking efficiency (%)

Dehusking efficiency is higher for lime water treated or water-treated proso millet. Model-2 machine was found very successful for de-husking all varieties of proso millet. Either water treatment and sun-dried one day before milling or sun-dried one day before milling at the moisture content 12-14% showed the good results. Power consumptions by machine was not too high and machine has overall good performance. The Model-2 has no frequent changeable parts so it may have long life. It can reduce the cost of processing of proso millet by 80% as compared to traditional processing. It has weight of about 60 kg including motor and frame is quite reasonable in transporting in remote areas.

CONCLUSIONS

The design, advancement and piloting of electric proso millet dehusker showed good results for simplification of processing of proso millet which is one of the major constraints for proso millet growers in high mountains of Karnali Province. It can reduce the work load significantly and time of postharvest processing of proso millet. It is economically sound with respect to traditional method of dehusking using human labor. The newly designed proso millet dehusker, could be the processing alternative that save time and reduce women's drudgery significantly in most remote mountain region of Nepal such as Humla, where farmers have no access to improved machinery for mechanical processing and women are most vulnerable in terms of food insecurity and high drudgery. The machine has provided a potential opportunity to save time, reduce drudgery and cost of processing and thereby promoting conservation, production and improving the value chain of proso millet.

RECOMMENDATIONS

Few machines have been fabricated and tested so far in the field. There is always oppourtunity to further refine and bring desired improvement in the machine to increase its effeciency. In proso millet dehusker also, the capacity of machine needs to be increased for commercial utilization. Speed variation facility in motor should be incorporated. It should be of modular design to transport in remote area. Further research for prior dehusking treatment on proso millet to get more whole grain is necessary. Electonic device like variable frequency drives (VFD) to be explored as additional product feature to help in de-husking different small millets using same de-husker. It is also necessary to dessiminate information and make easy access to these machines for farmers. For this, partnership with the private sector company is a most.

ACKNOWLEDGMENTS

The authors are grateful to the National Genebank, LI-BIRD site offices and the Local Crop Project (LCP) for financing to design, test and making arrangement to disseminate technology to the project sites. Special thank go to JB Workshop, Saatdoabato for manufacturing the *Chino Kutak*.

REFERENCES

Bhandari, GR, BK Joshi, D Gauchan, B Bhandari and S Panta. 2020. Simplifying the traditional processing system of minor millets. **In**: Good Practices for Agrobiodiversity Management (BK, Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NARC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

DHAN Foundation. 2019. Assessment of Existing Small Millet Processing Equipment in India. Report of the DHAN Foundation and McGill University.

Joshi BK and KH Ghimire. 2015. Proso millet cultivation and seed production technology. Briefing paper 4. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (in Nepali language).

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020. Nutritionally Unique Native Crop Landraces from Mountain Nepal for Geographical Indication Right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, R Shrestha, IP Gautam, AP Poudel and TP Gotame. 2019. Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Modak and Bapat 1994. Formulation of a generalized experimental model for a manually driven flywheel motor and its optimization. Applied Ergonomics **25**(1):199-122.

Parajuli A, A Subedi AR Adhikari, SR Sthapit, BK Joshi, D Gauchan and BR Sthapit. 2017. Baseline survey report: III. Chhipra, Humla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio against unpredictable environmental change in the Nepal Himalayas. Pokhara (Nepal): LI-BIRD/NARC/Bioversity International.

Rawat S, S Pant, N Pudasaini. 2019. Dudhe chino (Milky Proso millet): Introduction and cultivation practices, LI-BIRD, NAGRC, DoA, Bioversity International Nepal, Flyer 13.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Comparative Evaluation of Nutritional Value and Bioactive Components of Proso Millet, Foxtail Millet and Amaranth

Pravin Ojha, Roman Karki and Ujjwol Subedi

ABSTRACT

Nutritional profiling of mountain crops like proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*) and amaranth (*Amaranthus* spp.) was carried out through proximate analysis (moisture, crude fat, crude fiber, crude protein, total ash and carbohydrate), mineral content (iron, calcium and phosphorous), bioactive components (polyphenol and flavonoid) and antioxidant activity. Two land races of proso millet (Dudhe Chino and Hade Chino), two land races of foxtail millet (Raato Kaguno and Seto Kaaguno) and two species of amaranth [*A. caudatus* (Raato Latte, red) and *A. hypochondriacus* (Seto Latte, white)] were included in the study. The proximate component was almost similar in all tested crops. However, the lowest protein content (4.7%) and the highest crude fiber (16.9%) were found in Hade proso millet. Iron, phosphorous, calcium, polyphenol and flavonoid were found higher in amaranth compared to proso and foxtail millets. Phosphorous (97.19 mg/100 g) and calcium (175.72 mg/100 g) were higher in Seto Latte. Polyphenol (209.02 µg/100 g) and flavonoid (91.56 µg/100 g) were found the highest in Raato Latte. Also, antioxidant activity was found the highest (67.9%) in Raato Latte. Proximate composition, mineral content, bioactive components, and antioxidant activity were varied not only from one species of crop to another but also between the varieties of the crops.

Keywords: Antioxidant activity, calcium, crude fiber, mountain crops, polyphenol, protein

INTRODUCTION

Interest has been grown for crops grown in the mountains due to their potential health benefits and therapeutic applications. The potential benefits of proso millet (*Panicum miliaceum*), foxtail millet (*Setaria itallica)*, red amaranth (*Amaranthus caudatus*) and white amaranth (*A. hypochondriacus*) grown in the mid-hills and high hills of Nepal are yet to explore. They are neglected and underutilized crops but staple crop in many locations of Nepal (Joshi et al 2019). Recently one variety of amaranth has been released (Joshi et al 2017). Various studies have suggested that these grains are potential anti-diabetic agents and proved to increase plasma high-density lipoprotein (HDL) (Kim et al 2011, Cho and Ha 2003, Asao and Watanabe 2010). They have also been found to be effective against cardiovascular disease, obesity and have anti-tumor effect (Asao and Watanabe 2010, Park et al 2008, Nishizawa et al 2009, Aburai et al 2007).

Despite their importance proso millet, (called 'Chino' in Nepali), foxtail millet (Kaguno), amaranth (Latte/Maarse) stand outside the realm of the mainstay of Nepalese agriculture. However, Chino and Kaguno have been important crops of mid-western mountains of the country. Also, two species of amaranth, *A. caudatus* (Raato Latte, red) and *A. hypochodriacus* (Seto Latte, white) have also been cultivated in the mid and the high hills of Nepal from eons. There is no official data for the annual production of these underutilized grains. The present study was carried out to investigate the nutritional value and bioactive components of amaranths, proso millet and foxtail millet grown in Jumla, the high hill district of Nepal.

MATERIALS AND METHODS

Two landraces of proso millet (Dudhe Chino and Haade Chino), two landraces of foxtail millet (Raato Kaaguno, and Seto Kaaguno) and two species of amaranth (Raato Latte, red and Seto Latte) were collected from Agriculture Research Station of Nepal Agricultural Research Council (NARC), Jumla, Nepal. Despite efforts to collect more diverse cultivars, only two landraces were possible to obtain for the nutrition analysis.

Sampling research design and data analysis

Purposive sampling was done. For obtaining test samples, samples of the test crop species were divided into four quarters, and two cross-sectional quarters were taken and mixed while the other two quarters were discarded. The process was repeated until three test samples of 200 g each for all test crops were obtained. The experiment was setup in a completely randomized design with triplicate analysis for each parameter. The obtained results were analyzed by Tukey test for the significant difference using software SPSS version 20 at 5% level of significance. Mean and the standard deviation was also computed by the above software while the standard curve was prepared by using MS-Excel 2010.

Laboratory analysis

All test samples were milled separately by the barbender mill (Germany) and sieved to pass through a 0.25 mm screen.

Proximate analysis

The moisture content of the test samples was determined by drying the sample in a hot air oven to a constant weight (AOAC 2005). The protein contents of raw materials and the final product were calculated from the nitrogen content measured by the Kjeldahl method, multiplying total nitrogen by factor 6.25 (AOAC 2005). The fat content of the raw material and the final product was determined by continuous extraction in a Soxhlet apparatus for 3 hours using petroleum ether as a solvent (Ranganna 2008). The crude fiber content of the raw material and the final product was determined by (Ranganna 2008). The total ash content of the raw material and the final product was determined by incinerating the sample at 550°C in a muffle furnace (AOAC 2005). Total carbohydrate content was determined by the difference method as described by (Ranganna 2008): Carbohydrate (%) = 100 - (sum of crude protein, total ash, crude fiber, and crude fat).

Mineral content analysis

Calcium content was determined by the volumetric method. Fifty ml of the ash solution made, was transferred to a 250 ml beaker containing 50 ml of distilled water. Ten ml of saturated ammonium oxalate and 2 ml of methyl red indicator was added. This solution was made slight alkaline by adding dilute ammonia to faint yellow color and again made slightly acidic with few drops of acetic acid to faint pink color. The solution was then heated to boil and left overnight at room temperature. The solution was filtered using Whatman No. 42 paper and washed with distilled water until the filtrate is chloride free. The precipitate on the filter paper was collected in the 100 ml volumetric flask by breaking the point of filter paper using a glass rod and washing with hot, dilute H_2SO_4 (the filter paper has not tampered). Twenty-five ml of the solution was put into 3 conical flasks, warmed at 80°C and titrated, while still hot, with 0.01 N $KMnO_4$ to permanent pink color. The filter paper was then put into one of the conical flasks, used earlier, and titrated. The volume consumed by all four titrations was noted and calcium concentration was calculated as per AOAC (2005). Phosphorous and iron contents were determined by the spectrophotometric method (AOAC 2005)

Bioactive component estimation

Extracts of ground powder of each sample were prepared according to the method described by Sigdel et al (2018) with some modification. One g of powder was ground with absolute methanol (30 ml) and was kept under continuous shaking for 20 minutes and then was be filtered through Whatman no. 1 filter paper. The residue was again submitted to two more extraction cycles for 20 minutes each totalizing 60 minutes of extraction time. The filtrate was combined in a volumetric flask, and the volume was made up to 100 ml. The extracts were stored in a refrigerator for analysis of polyphenol, tannins, flavonoids and antioxidant activity.

Total phenol content (TPC): TPC was measured by using the Folin-Ciocalteu method, as described by Mahdavi et al (2011). One ml of extract or standard solution of gallic acid (100 µg/ml-1000 µg/ml) was decanted in a 25 ml volumetric flask, which contained 9 ml of distilled water. One ml of Folin-Ciocalteu reagent was added to the mixture and shaken. After 5 min, 10 ml of 7% Na_2CO_3 solution was added and the solution was diluted to volume with distilled water and mixed. After incubation for 90 min at room temperature, the absorbance against a prepared reagent blank (distilled water) was measured using an automated UV-VIS spectrophotometer at a wavelength of 765 nm. A standard solution of gallic acid was used to obtain a standard curve and the results were expressed as mg of gallic acid equivalents (GAE) per 100 g of sample.

Total flavonoid content (TFC): TFC was determined as described by Walvekar and Kaimal (2014) using the aluminum chloride assay through colorimetry. An aliquot (0.5 ml) of extracts were taken in different test tubes, added 2 ml of distilled water followed by the addition of 0.15 ml of sodium nitrite (5% $NaNO_2$, w/v) and allowed to stand for 6 min. Later, 0.15 ml of aluminum trichloride (10 % $AlCl_3$) was added and incubated for 6 min, followed by the addition of 2 ml of sodium hydroxide (NaOH, 4 % w/v) and volume was made up to the 5 ml with distilled water. After 15 min of incubation, the mixture turns to pink whose absorbance was measured at 510 nm using a colorimeter. Distilled water was used as blank. The calibration standard curve was prepared by preparing gallic acid solutions and results were expressed as mg of Gallic acid equivalents per 100 g of sample.

Antioxidant activity: Antooxidant activity was determined by the DPPH radical scavenging method as described by Walvekar and Kaimal (2014) with some modifications. The sample extract was again diluted by 30 times to give extract containing 0.3 mg powder extract per ml. Three ml extract was mixed with 3 ml of 0.004% DPPH solution and incubated in dark for 30 minutes. The absorbance was taken at 517 nm using a UV-Vis spectrophotometer. Absolute methanol was used as a blank. The scavenging activity of the extract against the stable DPPH was calculated using the following equation: $Scavenging\ activity\ (\%) = \frac{(A-B)}{A} x100$

Where, A is the absorbance of DPPH and B is the absorbance of DPPH and the extract combination.

RESULTS AND DISCUSSION

The proximate analysis of the test crops is shown in **Table** 1. The crude fat ranged from 4.63% (Raato Kaaguno) to 7.13% (Seto Latte). Seto Latte, Dudhe Chino (7.12%) and Seto Kaaguno (6.84%) were not significantly different for crude fat content. The crude protein was found in the range of 4.7% (Haade Chino) to 10.44% (Seto Latte). Seto Latte, Dudhe Chino, Raato Latte, and Raato Kaaguno were not significantly different for protein content. The ash content was found in the range of 2.34 (foxtail millet, white) to 4.81% (Dudhe Chino).

The crude fiber content was found in the range of 5.7 (Raato Latte) to 16.9% (Haade Chino). In general, it was lower in amaranth and higher in both foxtail and proso millets. The carbohydrate content was found in the range of 65.01-75.31%, with higher in amaranths and foxtail millet when compared with proso millet.

Table 1. Proximate analysis of amaranth, proso millet and foxtail millet

Sample	Moisture (%)	Crude fat (%)	Crude protein %	Total ash (%)	Crude fiber (%)	Carbohydrate (by difference) (%)
Raato Latte	11.30±0.30	6.04±0.25 ^{a}	9.34±0.13 ^{ab}	2.69±0.31 ^{ab}	6.62±0.23 ^{a}	75.31±0.42 ^{a}
Seto Latte	11.26±0.11	7.13±0.23 ^{b}	10.44±0.06 ^{a}	2.78±0.10 ^{ab}	5.70±0.29 ^{a}	73.93±0.23 ^{ab}
Haade Chino	8.81±0.35	6.92±0.24 ^{b}	4.70±0.22 ^{c}	4.07±0.18 ^{c}	16.90±1.00 ^{b}	67.41±1.05 ^{c}
Dudhe Chino	12.35±0.25	7.12±0.19 ^{b}	10.36±0.26 ^{a}	4.81±0.38 ^{d}	12.70±1.17 ^{cd}	65.01±1.93 ^{bc}
Raato Kaaguno	8.13±0.25	4.63±0.17 ^{c}	9.21±0.28 ^{ab}	3.10±0.26 ^{a}	10.43±0.31 ^{c}	72.62±1.03 ^{ab}
Seto Kaaguno	11.30±0.20	6.84±0.30 ^{b}	8.11±1.54 ^{b}	2.34±0.04 ^{b}	13.13±1.27 ^{d}	69.57±2.17 ^{ab}

Mean ±SD of three independent determinations. Different superscript letters in the same column are significantly different (p<0.05).

Kachiguma et al (2015) reported ash content of nine species of amaranth in the range of 4.41 to 8.73%, which were higher than the present results. The ash (%), protein (%), dietary fiber (%) and carbohydrate (%) of amaranth were 2.25, 19.85, 1.79, 1.81 and 77.82 respectively in amaranth of Nigeria (Abolaji et al 2017). The protein (%), fat (%), ash (%), total dietary fiber (%) and carbohydrate of foxtail millet of India were found to be 16.08, 4.86, 4.94, 10.7 and 54.04 respectively in wet basis as reported by Doddamani and Yengei (2018). The protein, fat and ash content of foxtail millet (seven species) and proso millet (three species) were reported to be in the range of 11.3-12.9, 3.6-3.9, 3.0-3.3 and 10.6-12.2, 3.3-3.5, 2.8-3.1 respectively by Vali Pasha et al 2017. The protein and fiber of proso millet were reported to be 1.5-13% and 9.6% respectively as reviewed by Kalonova et al (2007). These crops were found to have high protein content than basmati varieties of rice, which were in the range of 6-7.5% as reported by Ojha et al (2018).

The mineral content of the test crops is shown in **Table** 2. The iron, phosphorous and calcium were found to be significantly greater in amaranth species than in foxtail and proso millets. The iron (mg/100 g), phosphorous (mg/100 g) and calcium (mg/100 g) were found in the range of 3.26-10.64, 25.47-97.19, and 42.03-175.73, respectively. Kachiguma et al (2015) reported iron (mg/100 g) and calcium (mg/100 g) of amaranth in the range of 3.61-22.51 and 78.3-1004.6, respectively. The iron (mg/100 g) and calcium (mg/100 g) of amaranth were found to be 66 and 178.7, respectively. Doddamani and Yengei (2018) reported calcium (mg/100 g) and iron (mg/100 g) 32 and 5.75, respectively in foxtail millet. Vali Pasha et al (2018) reported the calcium (mg/100 g), iron (mg/100 g) and phosphorous (mg/100 g) of seven species of foxtail millet and three species of proso millet were in the range of 19-23, 28.7-38.6, 410-708 and 15-22, 42.3-55, 426-554, respectively. The calcium (mg/100 g), iron (mg/100 g) and phosphorous (mg/100 g) of proso millet and foxtail millet were found to be 8-20, 0.8-5.2, 156-230 and 10-21, 2.8-3.3, 310-360, respectively as reviewed by Kalonova et al (2007). The iron and calcium were higher in these crops compared to rice as reported by Ojha et al (2018) and Subedi et al (2018).

Table 2. Mineral content of amaranth, proso millet and foxtail millet

Sample	Iron (mg/ 100g)	Phosphorous (mg/100g)	Calcium (mg/100g)
Raato Latte	10.64±0.69 ^{a}	88.49±3.50 ^{a}	130.25±5.01 ^{a}
Seto Latte	10.57±0.1.07 ^{a}	97.19±01.78 ^{b}	175.73±6.12 ^{b}
Haade Chino	3.54±0.0.45 ^{b}	37.16±0.0.78 ^{c}	44.02±4.00 ^{cd}
Dudhe Chino	4.33±0.41 ^{b}	25.47±0.50 ^{d}	55.69±2.07 ^{e}
Raato Kaaguno	4.27±0.24 ^{b}	33.55±0.78 ^{c}	54.60±3.13 ^{ce}
Seto Kaaguno	3.26±0.31 ^{b}	52.46±1.36 ^{e}	42.03±2.00 ^{d}

Mean ±SD of three independent determinations. Different superscript letters in the same column are significantly different (p<0.05).

The polyphenol and flavonoid content of millet and amaranth are shown in Table 3. Phytochemicals were significantly higher in amaranth compared to proso and foxtail millets while antioxidant activity was found to be significantly higher in white amaranth. The polyphenol (mg GAE/100 g) and flavonoid (mg CE/100 g) of five amaranth species were found in the range of 27.52-30.76 and 8.91-9.56 mg/100 g, respectively as reported by Akin-Idowu et al (2017). The polyphenol (mg GAE/100 g) and radical scavenging activity (%) of foxtail millet were found to be 36.4 and 32.79%, respectively as reported by Doddamani and Yengei (2018). Vali Pasha et al (2018) reported phenol content (mg/100 g) and radical scavenging activity (%) of foxtail millet in the range of 74-87 and 13.3-20.6, respectively and of proso millet were in the range of 66-77 and 6-14%, respectively.

Table 3. Bioactive component of amaranth, proso millet and foxtail millet

Sample	Polyphenol (µg/100g)	Flavonoid (µg/100g)	Antioxidant (% RSA)
Raato Latte	209.02±11.40 ^{a}	91.56±1.91 ^{a}	59.83±1.05 ^{ac}
Seto Latte	149.39±2.51 ^{b}	68.45±1.72 ^{b}	67.89±2.59 ^{b}
Haade Chino	21.79±3.31 ^{c}	19.78±1.59 ^{c}	58±1.00 ^{ac}
Dudhe Chino	50.52±9.69 ^{d}	52.1±2.01 ^{d}	54.66±2.51 ^{a}
Raato Kaaguno	45.13±5.84 ^{d}	45.8±1.31 ^{e}	60±2.00 ^{c}
Seto Kaaguno	54.98±3.00 ^{d}	28.26±0.65 ^{f}	57.66±1.53 ^{ac}

Mean ±SD of three independent determinations. Different superscript letters in the same column are significantly different (p<0.05).

The different nutrient compositions within the species and even a variety of species can be attributed to climate, soil composition, harvesting time, post-harvest management (Hornick 1992).

CONCLUSIONS

The inference can be drawn that proximate constituents, mineral content, phytochemicals, and antioxidant activity differ not only between different crop species but also between the varieties of a crop species. Among crop species amaranth crop was found to be better in terms of nutritional quality compared to proso milelt and foxtail millet. Within amaranth cultivars, phosphorous and calcium were higher in Seto Latte variety while Polyphenol, flavonoid and antioxidant were found the highest in Raato Latte variety. Within proso millet cultivars, Dudhe Chino variety had higher calcium but lower phosphorous as compared to Hade Chino variety. Within foxtail millet cultivars, Seto Kaguno variety had higher phosphorous and lower calcium as compared to Rato Kaguno. Further comprehensive studies are needed covering diverse number of cultivars from different mountain locations for better validation of the findings.

REFERENCES

Abolaji GT, FM Olooto, DT Ogundele and EE Williams. 2017. Nutritional characterization of grain amaranth grown in Nigeria for food security and healthy living. Agrosearch **17**(2):1-10.

Aburai N, Y Esumi, H Koshino. 2007. Inhibitory activity of linoleic acid isolated from proso and Japanese millet toward histone deacetylase. Biosci. Biotechnol. & Biochem. **71**(8):2061-2064.

Akin-Idowu, PE, OA Odunola, MA Gbadegesin, OT Ademoyegun, AO Aduloju and YO Olagunju. 2017. Nutritional evaluation of five species of grain amaranth - an under-utilized crop. Int. J. Sci. **6**(1):18-27.

AOAC. 2005. Association of Official Analytical Chemists. Official methods of analysis. 18thed, Washington DC.

Asao M and K Watanabe. 2010. Functional and bioactive properties of quinoa and amaranth. Food Sci. & Technol. Res. **16**(2):163-168.

Cho SH and TY Ha. 2003. In vitro and in vivo effects of proso millet and sorghum on cholesterol metabolism. Food Sci. & Biotech. **12**(5):485-490.

Doddamani S and NB Yenagi. 2018. Nutrient composition of pre-treated foxtail millet rice. Int. J. Curr. Microbial. & App. Sci. **7**(2):1314-1322. https://doi.org/10.20546/ijcmas.2018.702.160.

Hornick SB. 1992. Factors affecting the nutritional quality of crops. Am. J. Alternative Agri. **7**(1-2):63-68.

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal, and BR Sthapit. 2017. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, Pokhara; NARC, Kathmandu and Bioversity International, Pokhara, Nepal. https://www.bioversityinternational.org/fileadmin/user_upload/Released_and_promising_crop_varieties.pdf

Joshi BK, R Shrestha, IP Gautam, AP Poudel and TP Gotame. 2019. Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Kachiguma NA, W Mwase, M Maliro, and A. Damaliphetsa. 2015. Chemical and mineral composition of amaranth (*Amaranthus* L.) species collected from central Malawi. J. Food Res. **4**(4):92-102.

Kim JS, TK Hyun, MJ Kim. 2011. The inhibitory effects of ethanol extracts from sorghum, foxtail millet and proso millet on alpha-glucosidase and alpha-amylase. Food Chem. **124**(4):1647-1651.

Mahdavi R, Z Nikniaz, M Rafraf and A Jouyban. 2011. Determination and comparison of the total polyphenol contents of fresh and commercial fruit juices. British Food J. **113**(6):744-752.

Nishizawa N, T Togawa, and KO Park. 2009. Dietary Japanese millet protein ameliorates plasma levels of adiponectin, glucose, and lipids in type 2 diabetic mice. Biosci. Biotechnol. & Biochem. **73**(2):351-360.

Ojha P, O Chaudhary, U Subedi, R Karki, and DMS Dongol. 2018. Milling, Nutritional, Physical and Cooking Properties of Four Basmati Rice Varieties. Nepal Agric. Res. J. **4**:18-24.

Park KO, Y Ito, T Nagasawa. 2008. Effects of dietary Korean proso-millet protein on plasma adiponectin, HDL cholesterol, insulin levels, and gene expression in obese type 2 diabetic mice. Biosci. Biotechnol. & Biochem. **72**(11):2918- 2925.

Ranganna S. 2008. Handbook of Analysis and Quality Control for Products. Tata McGraw- Hill Publishing Co Ltd, New Delhi; **pp**.1-30.

Sigdel A, P Ojha and TB Karki. 2018. Phytochemicals and syneresis of osmo-dried mulberry incorporated yoghurt. Food Sci. & Nutria. **6**(4):1045-1052.

Subedi U, R Karki, P Ojha, A Mishra, MB Shrestha and DMS Dongol. 2018. Degree of milling effect on cold water rice quality. Nepal Agric. Res. J. **4**:7-17.

Vali Pasha K, CV Ratnavathi, J Ajani, D Raju, S. Manoj Kumar, and SR Beedu. 2018. Proximate, mineral composition and antioxidant activity of traditional small millets cultivated and consumed in Rayalaseema region of south India. J. Sci. Food & Agri. **98**(2):652-660.

Walvekar S and P Kaimal. 2014. Comparitive study of effect of physical and chemical mutagens on phytochemical content and antioxidant activity of *Aegle marmelos* Corr. Int. J. Advanced Research. **2**(3):590-595.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Nutritionally Unique Native Crop Landraces from Mountain Nepal for Geographical Indication Right

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ABSTRACT

Continued cultivation of native crop landraces in a specific environment helps create geo-location specific traits such as quality, taste and some specific nutrient contents. Geographical indication (GI) provides premium price to farmers for such geo-location specific products and assures the conservation of crop landraces on-farm. Field, market and literature survey were conducted for Jumli Simee (bean) and Jumli Marsee (rice), and nutrient analysis were carried out in different mountain crop landraces for generating scientific evidence in support of their potential for geographical indication. The survey indicated that these landraces have geo-linked taste and they have been marketed in major cities by marking as the product of Jumla (ranging from 2000 to 3050 masl). Landrace name along with the production site has already become the brand for consumers and traders. Other crops' landraces might have similar geo-linked properties and thus merit further works. Some landraces have higher amount of nutrient content and possess unique taste and nutritive values. Based on the nutrient contents, landraces were grouped for different crops and some landraces' clusters have been found associated with geo-location. Iron content in proso millet landraces was significantly different among the three districts (Jumla, Humla and Dolakha). Significant differences among the districts were found on total ash, crude fiber, iron and calcium contents in foxtail millet landraces. Grow-out test within and outside GI regions might be needed for further validating the geo-linked properties. Trademark operating guidelines 2015, developed by the Department of Industry, has the provision of GI. Nepal has approved the National Intellectual Property Policy 2017 in which GI is included. Relevant stakeholders should support the potential communities to apply GI on their products and get benefited from the world along with assuring conservation of such native genetic resources.

Keywords: Geo-linked property, mountain crop landrace, nutrient content, geographical indication

INTRODUCTION

Continued cultivation of same landraces over the decades on same localities with stressful environment helps creates unique properties. Due to diverse geo-physical, climatic and soil variability across the country, Nepal has many landraces and agricultural products that are being marketed, sold and consumed by the name of production localities (Joshi et al 2017, Joshi et al 2020, Malla and Shakya 2004) from ancient time. This indicates that geographical indications (GIs) are in practice in Nepal informally and this system has created conducive environment for getting premium price and conserving these landraces by continued cultivation. However, none of such landraces and products have been registered legally on the regime of GI in Nepal. A GI is a sign (or name) used on products that have a specific geographical origin and possess unique qualities or a reputation associated with the product of the origin (WIPO 2004). The qualities, characteristics or reputation of the product should be essentially due to the place of origin. GI is an intellectual property that protects the product of the area and ultimately helps to promote conservation of agrobiodiversity on-farm and boost economy of local community. The well-known examples of GIs in South Asia include Basmati rice, Himalayan water, Alphonso mango, Bhutanese red rice, etc.

The Government of Nepal has approved the National Intellectual Property Right Policy (2017) which includes Copyrights, Patents, Industrial design, Trademarks, GI, Varietal protection, Trade secrets and Traditional knowledge policies (MoICS 2017). Among these policies, GI gives exclusive right to a region or a landscape (eg village, town/city, province or country) to use a name for a particular product with certain characteristics that corresponds to their specific location. The Government of Nepal is also strongly favoring GI by joining World Intellectual Property Organization (WIPO) in 1997 and becoming a member of World Trade Organization (WTO) in 2004.

The first and most important part to obtain GI right on any particular agricultural product is to generate both empirical and research-based information. Research should be designed to further verify the GI properties after the extensive survey on potential GI-related agricultural genetic resources (AGRs). Most of the products possess greater cultural and age-old traditional values. Important indigenous crop landraces and their products might have linked with particular geography, which should therefore, be protected with GI by developing suitable legislation and generating GI-related authentic information for their market promotion, on-farm conservation and livelihood enhancement of local communities. This study has been conducted with the objectives to i) identify and verify the geo-linked genes and traits of native agricultural genetic resources and products associated with particular location; ii) increase understanding through the use of geographical indicator for the promotion of landraces and products; and ii) encourage relevant experts, researchers and institutions to conduct in depth research and register geo-linked products and link GI for on-farm conservation of agrobiodiversity and improve livelihoods of particular local communities. .

MATERIALS AND METHODS

We conducted literature survey, focus group discussion, key informant survey (KIS), market survey and nutrition analysis of the landraces of the traditional mountain crops. Relevant journal and proceedings papers, books, websites, reports were reviewed focusing on information associated with GI. Four focus group discussions (two male and two female groups) were organized in Haku and Depal Gaun, Jumla for Jumli Simee (bean) and Jumli Maarsee (rice). Under the KIS, we interviewed 3 traders, 5 consumers, 5 growers and 5 R&D officers in Jumla. Market survey was conducted in Nepalgunj, Kathmandu and Pokhara. Focus group discussion, key informant survey and market survey were done only on Jumli Simee and Jumli Maarsee in Jumla and some cities. Nutrition analysis of crop landraces were carried out after they are evaluated in the fields in project sites. Grow-out tests could not be carried out due to time and other technical constraints. The information and data collected were statistically analyzed (eg ANOVA, cluster analysis and other methods).

Nutrition analysis

Two sets of landraces were used for nutrition analysis in Food Research Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur. First set was of elite landraces that were evaluated in Jumla, Humla, Lamjung and Dolakha sites of the project. Detail of this set is given in **Table** 1. There were 20 landraces of traditional mountain crops of foxtail millet, bean, finger millet, amaranth, and rice in the first set. These landraces were collected from Rasuwa, Jumla, Dadeldhura, Bajhang, Sankhuwasabha, Mustang, and Lamjung districts. Twelve different nutrient parameters were analyzed for this first set of landraces. In the case of rice and bean, completely randomized design (CRD) was followed with 2 replications. In the second set, there were 54 landraces of proso millet, foxtail millet, sorghum, amaranth, finger millet, buckwheat, lentil and bean which were collected from Jumla, Dolakha, Humla and Rasuwa districts. Two food items ie *latte laddu* (sweet ball) and buckwheat cookies were also included in the nutrient analysis. Second set materials were analyzed for 9 different nutrient parameters. Method of nutrient analysis is described in Ojha et al (2020).

Statistical analysis

CRD-based nutrient data of bean and rice of the first set of materials were analyzed following the conventional analysis of variance (ANOVA) method. Least significant difference (LSD) and coefficient of variation (CV) were also estimated. Means were presented for other non-replicated data (of foxtail millet, amaranth, and finger millet). Mean values of each of 19 landraces were subjected to cluster and principal component analyses (one landrace was excluded from multivariate analysis because of missing values). For the second set of materials, just mean values were presented and compared with quinoa and each other. In case of proso millet and foxtail millet, further F test was applied considering district as factor variable in CRD model to see the differences among the districts. Fifty-four landraces of the second set of materials, including quinoa were further analyzed using cluster and principal component methods. All analyses were done using R statistical software after processing data in MS Excel.

Table 1. Passport details of some crop accessions used in nutrient analyses

SN	Accession	Landrace	Farmer's name	Collection site	Lat (N) / Long (E)	Altitude (m)
Rice						
1.	NGRC03234	Boraang	Laktaman Tamang	Goljung-5, Rasuwa	28.1167 / 85.2833	1947
2.	NGRC07931	Jumli Marsee	Hari Datta Rokaya	Lamra-2, Srinagar, Jumla	29.25333 / 82.12444	2487
3.	NGRC03070	Saali Dhaan	Radha Devi Bhatta	Amargadhi -9, Dadeldhura	29.2167 / 80.4667	1340
4.	NGRC05018	Hansaraaj	Padam Malla	Bagthala, Banjh-8, Bajhang	29.4906 / 80.8981	1307
Amaranth						
5.	NGRC06843	Raato Maarse	Dev Giri	Byalkatia, Talium-3, Jumla	-	-
Finger millet						
6.	NGRC05113	Raato Kodo	Bhawani Seed Bank	Talium- 7, Jumla	29.225 / 82.2583	-
Bean						-
7.	NGRC06086	Asaare Simee	Bhoaman Jimi	Tamajahok-5, Sankhuwasabha	27.6 / 87.3333	1460
8.	NGRC06082	Sthaaniya Raato	Til Bahadur Rawal	Talium-2, Jumla	29.225 / 82.2583	-
9.	NGRC06072	Sthaaniya Kaalo	Til Bahadur Rawal	Talium-2, Jumla	29.225 / 82.2583	-
10.	NGRC02235	Ghiu Simee	-	Marpha, Mustang	28.7833 / 83.725	2600
11.	NGRC04485	Khairo Simee	-	Jaira, Humla	30 / 81.9	2220
12.	NGRC02241	Maale Pahenlo Simee	-	Dandaphaya, Humla	30 / 81.9	2500
13.	NGRC06059	Kaalo Simee	Chandamaya Jimi	Tamajhok-5, Sankhuwasabha	27.6 / 87.3333	1185
14.	NGRC05971	Seto Simee	-	Rasuwa	28.1167 / 85.2833	-
15.	NGRC05970	Chhirke Simee	-	Rasuwa	28.1167 / 85.2833	-
16.	NGRC02240	Laamo Simee	-	Lamkoria, Mustang	28.7833 / 83.725	1200
Foxtail millet						
17.	-	Raato Kaaguno	-	Jumla	-	-
18.	-	Kaalo Kaaguno	-	Ghanpokhara, Lamjung	-	-
19.	-	Tinmaase Kaaguno	-	Ghanpokhara, Lamjung	-	-
20.	-	Bariyo Kaaguno	-	Ghanpokhara, Lamjung	-	-

-, information not available; Lat, latitude; Long, longitude.

RESULTS AND DISCUSSION

Survey findings

Field survey on GI-related issues in Jumla revealed that Jumli Simee (bean) and Jumli Maarsee (rice) have different taste than other landraces or modern varieties grown in Jumla. Respondents also claimed that similar taste may not be found if these landraces are grown in other districts. They distinguish these Jumli landraces from other landraces based on seed morphology. They are grown from 2000 to 3050 m areas in Jumla. Farmers are also getting premium price from these landraces. The major uniqueness of these landraces is high diversity within landraces and excellent taste. There is high demand of these landraces, and visitors prefer to eat and take the products with them. Consumers are willing to pay high price for quality, tasty and nutritious agricultural products. In Nepalgunj, Jumli Maarsee rice costs twice the cost of other rice landraces, and Jumlee Simee (bean) costs 40% more than other bean landraces. In Kathmandu, consumers are paying 3 to 4 times higher price for Jumli Maarsee rice compared to other common coarse grain rice. The price of Jumli bean is 20-25% higher than other beans in Kathmandu. Product names associated with landraces are highly valued both in local and city markets. We found these products in different shops, supermarkets and department stores, which are labeled with the geo-location name ie Jumla. These landraces are in general grown organically with organic manure and no use of external chemical inputs as there is a belief that taste of these native crop landraces deviates from their original taste if grown with chemical fertilizers. Survey analysis indicated that Jumli Simee and Jumli Maarsee rice have quality of getting GI right from all locations of Jumla district.

Nutrient analysis: First set of landraces

There were significant differences among bean landraces for all nutrient contents (moisture, fat, ash, protein, iron, phosphorous, calcium, polyphenol, flavonoid and antioxidant) (**Table** 2). Rice landraces were found significantly different for moisture, fat, protein, calcium, polyphenol and antioxidant contents. Fat was found higher in Asaare Simee among the bean landraces. Seto Simee was top for carbohydrate. Ghiu Simee was best for the highest content of ash, iron and phosphorous. Sthaaniya Kaalo Simee possesses the highest percentage of protein, whereas Sthaaniya Raato was top for fiber, calcium, polyphenol, flavonoid and antioxidant. Farmers prefer Sthaaniya Kaalo to include in their mixture which is very good for protein. Within rice landraces, fat was highest in Saali Dhaan. Jumli Maarsee was top for the amount of protein, polyphenol, flavonoid and antioxidant. Hansaraaj Dhaan possess the highest amount of ash, fiber and carbohydrate. The iron, calcium, and phosphorous was found high in the Boraang Dhaan. None of landraces was equally rich in all nutrient contents; therefore, mixture practices would seem better to make the production nutrition rich. Further, consuming these mixed varieties together will provide dense nutrient in a plate.

Table 2. Nutrient composition of different native crop landraces listed in Table 1

SN	Landrace	MSTR	CFa	TA	CP	CF	CHO	Fe	P	Ca	PLY	FLV	AO
Amaranth													
1	Raato Latte	11.36	5.95	2.10	21.73	5.59	58.88	4.20	200.19	288.17	144.35	73.29	17.74
Finger millet													
1	Raato Kodo	12.51	0.73	2.21	6.87	11.01	77.69	3.20	228.84	392.68	93.42	41.92	57.02
Foxtail millet (FTM)													
1	Raato Kaaguno	10.95	4.24	3.06	6.05	13.36	75.70	3.53	334.84	41.83	142.00	131.9	23.55
2	Kaalo Kaaguno	10.55	4.72	1.77	9.67	19.64	73.29	2.12	246.66	68.23	137.60	103.2	15.12
3	Tinmaase Kaaguno	9.19	3.90	0.80	9.53	13.86	76.58	1.92	84.46	155.02	-	-	-
4	Bariyo Kaaguno	11.23	4.35	1.98	8.73	11.46	73.71	5.50	234.34	54.28	93.31	72.13	19.83
	Average (FTM)	**10.48**	**4.30**	**1.90**	**8.50**	**14.58**	**74.82**	**3.27**	**225.08**	**79.84**	**124.30**	**102.4**	**19.50**
5	Bariyo Kaaguno (milled grain)	8.73	4.46	1.80	5.81	2.34	79.20	0.20	56.42	215.95	-	-	-
Bean													
1	Asaare Simee	9.75	1.46	5.21	31.94	11.93	51.63	8.80	690.74	274.88	38.16	36.31	27.24
2	Chhirke Simee	9.53	1.38	3.70	25.91	9.05	59.48	3.87	418.05	260.37	128.90	79.19	54.46
3	Kaalo Simee	9.77	1.14	4.46	25.77	9.79	58.86	6.62	496.97	241.80	62.19	47.59	32.57
4	Khairo Simee	10.23	1.25	4.44	23.65	9.26	60.42	7.25	382.83	143.69	73.52	48.85	38.67
5	Laamo Simee	10.12	1.18	3.73	32.29	9.00	52.68	3.44	364.65	212.30	143.41	73.02	69.18
6	Maale Simee	10.56	1.02	4.36	29.37	11.16	54.70	5.80	513.62	195.94	94.53	44.28	65.16
7	Seto Simee	9.93	1.37	4.43	22.63	9.89	61.64	6.52	473.15	271.94	63.09	42.86	18.15
8	Ghiu Simee	10.73	1.15	5.34	26.91	11.37	55.87	9.07	711.80	246.88	74.05	41.96	48.89
9	Sthaaniya Kaalo	10.15	0.94	4.88	33.76	12.48	50.28	7.45	448.22	199.35	63.91	44.90	69.04
10	Sthaaniya Raato	10.86	0.97	4.43	29.52	14.34	54.22	7.08	494.03	292.82	320.50	101.9	92.99
	Average (bean)	**10.16**	**1.19**	**4.50**	**28.18**	**10.83**	**55.98**	**6.59**	**499.41**	**234.00**	**106.23**	**56.09**	**51.64**
	p-value	0.001	0.00	0.00	0.004	0.0034	0.006	0.00	0.0020	0.0192	0.0000	0.000	0.000
	LSD, 0.05	0.849	0.44	0.62	8.663	3.8236	9.323	3.07	239.38	126.33	47.941	24.00	24.1
	CV, %	2.11	9.39	3.50	7.77	8.92	4.21	11.8	12.11	13.64	11.40	10.81	11.78
Rice													
1	Boraang Dhaan	12.98	2.04	1.10	8.35	1.89	73.63	1.60	59.98	106.89	82.66	57.10	22.07
2	Hansaraaj Dhaan	12.11	2.28	1.34	7.52	2.89	73.88	0.40	52.53	86.25	70.41	46.80	17.46
3	Jumli MaarseeDhaan	12.24	2.20	1.23	9.86	2.01	72.47	0.57	57.54	66.70	204.83	83.32	75.66
4	Saali Dhaan	12.65	2.48	1.07	8.53	2.27	73.00	1.06	51.92	73.79	73.76	55.71	17.20

SN	Landrace	MSTR	CFa	TA	CP	CF	CHO	Fe	P	Ca	PLY	FLV	AO
	Average (rice)	**12.50**	**2.25**	**1.19**	**8.56**	**2.26**	**73.24**	**0.90**	**55.49**	**83.41**	**107.92**	**60.73**	**33.10**
	p-value	0.011	0.01	0.06	0.000	0.0942	0.159	0.37	0.4809	0.0096	0.0010	0.091	0.026
	LSD, 0.05	0.402	0.19		0.486					16.747	33.653		35.98
	CV, %	1.16	3.09	6.26	2.05	13.26	0.71	71.4	9.99	7.23	11.23	17.34	39.16

Only bean and rice landraces were statistically tested. MSTR, moisture (%); CFa, crude fat (%); TA, total ash (%); CP, crude protein (%), CF, crude fiber (%); CHO, carbohydrate (%); Fe, iron (mg/100g); P, phosphorous (mg/100g); Ca, calcium (mg/100g); PLY, polyphenol (mg GAE/100g); FLV, flavonoid (mg GAE/100g); AO, antioxidant (%); -, data missing. Nutrient analysis was done on dehulled rice grains.

The highest fat content was found in Raato Latte (amaranth) followed by Kaalo Kaaguno among the 20 landraces of 5 crops (amaranth, foxtail millet, bean, rice and finger millet) (**Table** 2). The lowest fat was observed in Raato Kodo (finger millet). Based on the amount of ash (minerals) content, Ghiu Simee and Asaare Simee come first and second rank whereas Tinmaase Kaaguno has the lowest ash. Protein content of Sthaaniya Kaalo Simee was highest followed by Laamo Simee. Raato Kaaguno has the lowest protein content. Fiber was found higher in Kaalo Kaaguno and Sthaaniya Raato Simee. The lowest fiber was of Boraang Dhaan. The highest and the lowest carbohydrate were of Raato Kodo and Sthaaniya Kaalo Simee, respectively. The iron in Ghiu Simee was the highest and the lowest iron was of Hansaraaj Dhaan. The calcium content in Raato Kodo and Raato Kaaguno were the highest and the lowest, respectively. Sthaaniya Raato Simee possesses the polyphenol, and antioxidant the highest amount, whereas Jumli Maarsee rice was second for these two nutrients. Asaare Simee has the lowest polyphenol and flavonoid. Flavonoid in Raato Kaaguno was the highest in amount. The antioxidant was the lowest in Kaalo Kaaguno.

Clustering of 19 landraces based on 12 nutrients made 4 clusters with 7 landraces grouped in cluster III (**Table** 3). The landraces with high calcium, phosphorous and antioxidant content fall under cluster I. The landraces with high amount of fat, fiber, carbohydrate, and flavonoid grouped under cluster II. The mean values of ash, protein, iron and phosphorous were the highest in cluster III. Based on these 13 nutrients, clusters were formed as per the crops for rice, bean and foxtail millet landraces (**Figure** 1). Raato Kodo and Raato Latte were found similar based on these nutrients. Among the four rice landraces, Jumli Maarsee was found different.

Table 3. Average nutrient value of each cluster of landraces shown in Figure 1

Nutrient	Cluster			
	I	II	III	IV
Cluster member, n	5	3	7	4
Moisture (%)	10.88	10.91	10.16	12.50
Crude fat (%)	2.04	4.44	1.19	2.25
Total ash (%)	3.23	2.27	4.73	1.19
Crude protein (%)	23.26	8.15	27.72	8.57
Crude fiber (%)	9.80	14.82	10.84	2.27
Carbohydrate (%)	60.59	74.23	56.20	73.25
Iron (mg/100g)	4.36	3.72	7.36	0.91
Phosphorous (mg/100g)	341.15	271.95	531.05	55.49
Calcium (mg/100g)	289.27	54.78	224.93	83.41
Polyphenol (mg/100g)	166.12	124.30	67.06	107.92
Flavonoid (mg/100g)	73.88	102.44	43.82	60.73
Antioxidant (%)	58.28	19.50	42.82	33.10

Two principal components explained 68% of total variation (**Table** 4). Ash and crude protein contributed higher in PC1. The loading values of polyphenol and flavonoid were higher in PC2, whereas, the values of antioxidant and polyphenol were higher but negative in PC3. Plotting of these 19 landraces using PC1 and PC2 under different districts indicated that nutrient contents in these landraces are associated with geo-locations (**Figure** 2), so there is a potential of considering these landraces under GI.

Figure 1. Clustering of 19 landraces of 5 crops based on 12 different nutrient contents (see Table 1 for details of these landraces).

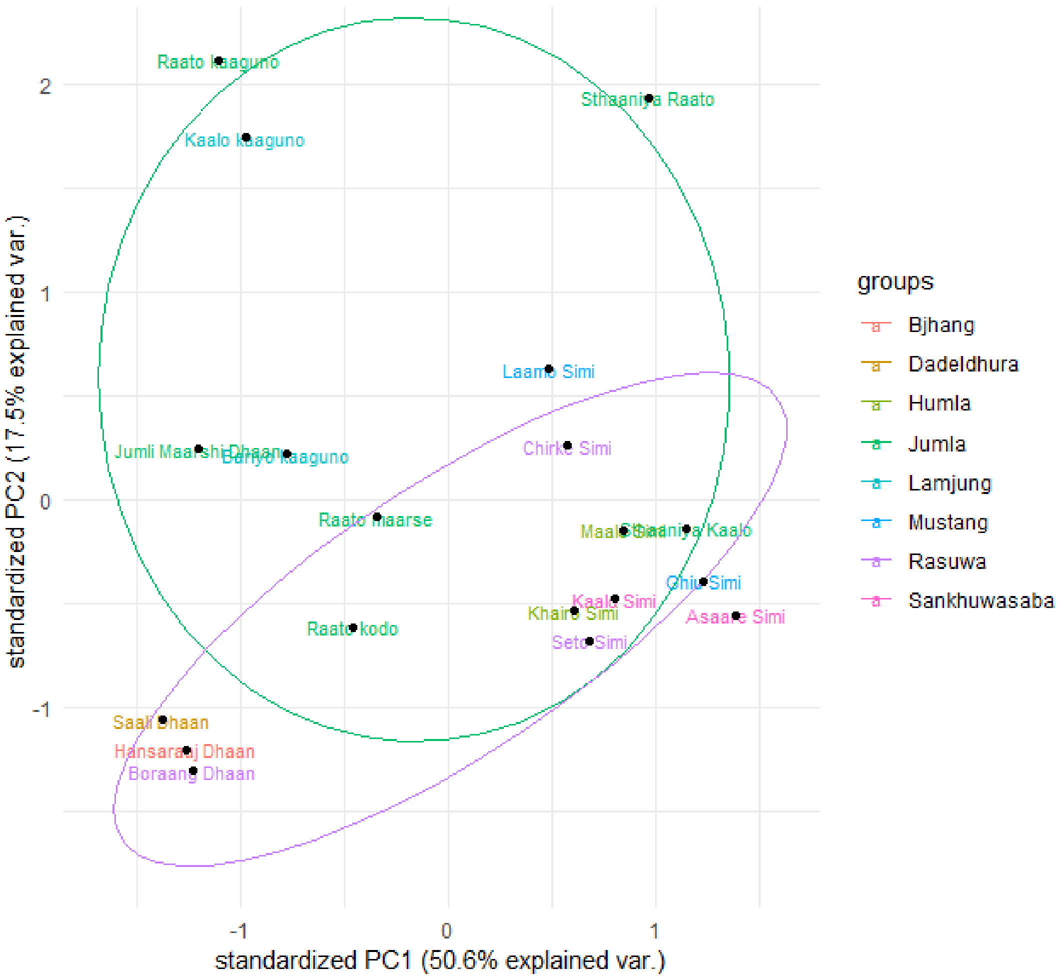

Figure 2. Plotting of 19 landraces of mountain crops based on nutrient contents using the first and second principal components (see Table 1 for detail of these landraces).

Table 4. Eigen analysis and principal component (PC) coefficients based on 12 variables measured in 19 landraces collected from different districts of Nepal

Nutrient	PC1	PC2	PC3	PC4	PC5
Standard deviation	2.564	1.508	1.318	0.919	0.798
Proportion of variance	0.506	0.175	0.134	0.065	0.049
Cumulative proportion	0.506	0.681	0.814	0.879	0.928
Moisture (%)	-0.305	-0.194	-0.270	0.101	0.248
Crude fat (%)	-0.230	0.220	0.329	-0.566	0.209
Total ash (%)	0.374	0.067	0.105	0.112	-0.100
Crude protein (%)	0.364	0.023	-0.085	-0.208	-0.221
Crude fiber (%)	0.170	0.436	0.306	0.290	0.286
Carbohydrate (%)	-0.355	-0.018	0.076	0.287	0.232
Iron (mg/100g)	0.347	0.024	0.193	-0.042	0.133
Phosphorous (mg/100g)	0.359	0.107	0.176	0.117	0.047
Calcium (mg/100g)	0.259	-0.093	-0.190	0.048	0.785
Polyphenol (mg/100g)	-0.035	0.472	-0.474	-0.240	0.143
Flavonoid (mg/100g)	-0.154	0.583	-0.028	-0.153	-0.069
Antioxidant (%)	0.174	0.199	-0.585	0.239	-0.149

Nutrient analysis: Second set of landraces

The results of nine nutrients for 54 landraces of proso millet, foxtail millet, sorghum, amaranth, quinoa, finger millet, buckwheat, bean, and lentil are given in Table 5. Three modern varieties, one each of rice, wheat and maize are also included along with food value of *Latte Laddu* (amaranth) and buckwheat cookies. Two Chino landraces (Chino Co 4654 and Chino Humla 725) (proso millet) had the highest amount of fat and ash contents among the 54 landraces and the three modern varieties of rice, wheat and maize. The protein content was highest in Kaalo Musuro (lentil) whereas the fiber content was highest in Kaaguno Humla 522 (foxtail millet). Quinoa and modern varieties of rice, wheat and maize crops have higher carbohydrate. Latte Acc#4 and Latte Ac#3 had the highest amount of iron and phosphorous, respectively. The highest amount of calcium was found in Gumki Kaaguno and Seto Kaaguno (foxtail millet).

Table 5. Nutritional composition of native crop landraces collected from different geolocations

Landrace	Site	MSTR	CFa	TA	CP	CF	CHO	Fe	P	Ca
Proso millet										
Dude Chino	Jumla	10.95	4.14	4.02	6.86	13.02	61.01	6.57	11.52	684.1
Haade Chino	Jumla	11.2	4.16	3.92	6.53	11.77	62.42	8.87	11.14	506.93
Haade Chino-1	Jumla	8.74	6.32	3.88	4.51	17.12	59.43	3.11	36.47	44.08
Chino Dude-1	Jumla	12.36	6.23	4.5	9.77	11.95	55.19	4.01	25.40	55.07
Average		**10.81**	**5.21**	**4.08**	**6.92**	**13.47**	**59.51**	**5.64**	**21.13**	**322.55**
Chino CO 4651	Dolakha	6.97	6.79	6.92	7.19	14.65	72.13	2.04	18.98	122.40
Chino CO 3149	Dolakha	6.95	6.83	7.01	7.02	7.93	72.19	1.00	16.90	143.98
Chino CO 4656	Dolakha	6.89	7.15	6.73	6.79	15.31	72.44	1.45	18.61	149.33
Chino CO4645	Dolakha	7.07	6.93	7.08	7.21	11.94	71.71	5.12	15.11	142.40
Chino CO 4654	Dolakha	10.93	10.85	10.96	10.97	17.08	56.29	4.60	18.84	51.71
Average		**7.76**	**7.71**	**7.74**	**7.84**	**13.38**	**68.95**	**2.84**	**17.69**	**121.96**
Chino Humla 312	Humla	11.28	4.49	3.17	10.06	14.61	56.39	2.84	86.37	45.98
Chino Humla 383	Humla	11.36	4.8	3.94	10.05	18.34	51.51	2.18	138.61	53.6
Chino Humla 488	Humla	7.42	7.43	7.48	7.34	12.19	70.33	1.93	22.68	243.06
Chino Humla 239	Humla	10.90	10.75	10.72	11.22	11.85	56.41	2.58	18.79	54.16
Chino Humla 725	Humla	10.89	11.05	10.85	10.76	7.45	56.45	3.29	19.29	96.53
Chino Humla	Humla	6.95	6.96	6.90	6.98	15.39	72.21	1.55	15.95	120.02
Chino Humla 530	Humla	6.90	6.71	6.98	7.01	15.55	72.40	1.37	17.89	126.61
Chino Humal 653	Humla	10.73	10.51	10.77	10.91	15.81	57.08	0.69	18.09	276.70
Average		**9.55**	**7.84**	**7.60**	**9.29**	**13.90**	**61.60**	**2.05**	**42.21**	**127.08**
Foxtail millet										
Gumki Kaaguno	Jumla	10.63	4.18	2.82	5.6	9.41	67.36	6.5	10.58	752.27
Seto Kaaguno	Jumla	9.08	5.64	3.17	5.74	11.6	64.77	5.84	11.45	706.28
Raato Kaaguno	Jumla	12.61	4.79	2.84	7.24	8.19	64.33	5.53	12.26	574.98
Seto Kaaguno-1	Jumla	11.31	6.1	2.13	7.77	13.18	59.51	2.98	51.38	42.08
Raato Kaaguno-1	Jumla	8.09	4.27	2.96	8.88	9.52	66.28	4.01	32.65	51.81
Average		**10.34**	**5.00**	**2.78**	**7.05**	**10.38**	**64.45**	**4.97**	**23.66**	**425.48**
Kaaguno Co1896	Dolakha	7.02	6.95	7.07	7.03	15.62	71.93	1.63	22.21	176.18
Kaaguno CO3475	Dolakha	6.02	5.84	5.97	6.25	14.88	75.92	1.31	18.81	127.45
Kaaguno CO 3474	Dolakha	10.48	10.57	10.58	10.30	8.20	58.07	2.68	16.33	41.49
Average		**7.84**	**7.79**	**7.87**	**7.86**	**12.90**	**68.64**	**1.87**	**19.12**	**115.04**

Landrace	Site	MSTR	CFa	TA	CP	CF	CHO	Fe	P	Ca
Kaaguno Humla 213	Humla	10.83	5.32	2.87	7.89	13.47	59.63	3	115.23	65.67
Kaaguno Humla 606	Humla	10.88	4.07	2.78	6.37	14.25	61.65	1.7	47.82	37.32
Kaaguno Humla 523	Humla	6.87	7.07	6.69	6.85	16.09	72.52	2.12	10.71	61.27
Kaaguno Humla 379	Humla	6.74	6.86	6.56	6.81	8.22	73.03	0.81	11.82	62.49
Kaaguno Humla 163	Humla	6.90	6.94	6.80	6.97	15.25	72.39	1.37	11.41	59.53
Kaaguno Humla 631	Humla	6.66	6.43	6.68	6.87	15.63	73.36	1.46	18.12	155.70
Kaaguno Humla 468	Humla	6.15	6.15	5.96	6.33	14.43	75.41	1.93	16.18	43.75
Kaaguno Humla 522	Humla	6.58	6.46	6.64	6.63	21.56	73.69	1.53	19.19	54.25
Kaaguno Humla 524	Humla	10.43	10.60	10.38	10.31	19.08	58.28	1.74	16.28	41.97
Kaaguno Humla	Humla	10.46	10.38	10.59	10.41	18.66	58.16	2.27	14.79	53.83
Average		**8.25**	**7.03**	**6.60**	**7.54**	**15.66**	**67.81**	**1.79**	**28.16**	**63.58**
Sorghum										
Seto Junelo-1	Jumla	5.69	3.76	1.77	5.31	2.81	80.66	2.22	39.57	25.72
Raato Junelo	Jumla	5.53	4.24	2.55	7.77	8.56	71.35	7.49	96.03	52.66
Junelo	Jumla	4.59	6.79	6.99	5.57	18.4	76.06	5.06	19.62	126.17
Average		**5.27**	**4.93**	**3.77**	**6.22**	**9.92**	**76.02**	**4.92**	**51.74**	**68.18**
Amaranth										
Latte Kathachour-9	Jumla	6.26	6.18	6.31	6.28	4.98	74.97	1.56	33.35	283.91
Latte ACC#4	Dolakha	6.16	5.97	6.10	6.42	4.28	75.35	9.16	38.64	202.66
Latte ACC#6	Dolakha	6.37	6.70	6.24	6.18	5.45	74.51	6.68	34.80	146.23
Latte ACC#2	Dolakha	6.06	6.05	5.95	6.18	4.87	75.76	4.70	35.88	138.65
Latte ACC#10	Dolakha	10.53	9.78	4.09	17.45	6.15	52.01	6.54	247.60	23.19
Latte ACC#3	Dolakha	10.47	10.03	4.57	16.23	8.8	49.91	5.6	364.48	23.19
Average		**7.64**	**7.45**	**5.54**	**9.79**	**5.76**	**67.09**	**5.71**	**125.79**	**136.31**
Quinoa										
Quinoa 1		5.52	0.88	0.45	7.35	1.19	84.61	2.33	-	41.76
Quinoa 2		4.93	1.64	0.74	7.17	1.34	84.18	2.95	-	31.77
Average		**5.23**	**1.26**	**0.60**	**7.26**	**1.27**	**84.40**	**2.64**		**36.77**
Finger millet										
Okhle-1 Kodo	Dolakha	13.29	1.79	2.78	7.08	6.64	68.42	3.87	329.07	196.47
Sailung-1 Kodo	Dolakha	12.42	1.19	2.86	7.34	6.84	69.35	2.2	302.44	183.04
Kavre-1 Kodo	Dolakha	12.50	2.33	2.94	4.99	4.52	72.72	3.78	335.04	239.68
Average		**12.74**	**1.77**	**2.86**	**6.47**	**6.00**	**70.16**	**3.28**	**322.18**	**206.40**
Buckwheat										
Tite faapar ACC#2223	Dolakha	12.99	2.05	2.07	11.36	1.83	69.70	2.45	184.29	74.05
Tite faapar ACC#2227	Dolakha	13.38	2.95	2.05	13.35	1.17	67.10	1.04	108.2	53.36
Average		**13.19**	**2.50**	**2.06**	**12.36**	**1.50**	**68.40**	**1.75**	**146.25**	**63.71**
Bean										
Khairo Simee	Dolakha	9.14	0.73	4.71	12.29	6.03	67.10	6.40	1.23	141.96
Thulo Pahenlo Simee	Dolakha	10.31	1.02	4.94	9.80	5.50	68.44	4.77	1.00	138.05
Average		**9.73**	**0.88**	**4.83**	**11.05**	**5.77**	**67.77**	**5.59**	**1.12**	**140.01**
Lentil										
Kaalo Musuro	Rasuwa	6.07	0.20	3.04	24.96	8.65	57.08	6.03	0.46	111.84
Modern varieties										
Dhaulagiri wheat		11.51	1.37	1.63	5.13	8.1	80.37	5.91	74.08	102.85
Posilo Makai 2, maize		10.88	6.31	1.31	8.53	3.76	69.21	0.57	174	127
LPNBR 1632 rice		11.59	0.94	0.81	6.25	0.86	80.41	2.77	72.76	148.31
Food item										
Latte laddu		16.96	1.37	2.26	3.45	5.99	-	1.09	146.27	154.48
Buckwheat cookie		8.13	6.83	2.29	8.5	1.04	-	3.88	99.10	38.64

MSTR, moisture (%); CFa, crude fat (%); TA, total ash (%); CP, crude protein (%), CF, crude fiber (%); CHO, carbohydrate (%); Fe, iron (mg/100g); P, phosphorous (mg/100g); Ca, calcium (mg/100g). -, data missing. Samples of foxtail and proso millets from Dolakha are not originally collected from Dolakha and their origin places are not known.

Within proso millet and foxtail millet, Dude Chino (proso millet) had the highest amount of flavonoid and tannin (**Table** 6). Raato Kaaguno (foxtail millet) had highest polyphenol whereas Seto Kaaguno possessed the highest amount of antioxidant. Significant difference was found among the three districts for iron content of proso millet (**Table** 7). Proso millet landraces from Jumla showed the highest iron content. In case of foxtail millet, significant difference was found among the districts in ash, fiber, iron and calcium contents. Foxtail millet landraces from Dolakha had the higher amount of ash, whereas, landraces from Humla had higher amount of fiber as compared to other districts. Landraces from Jumla had shown the highest iron and calcium contents.

Table 6. Additional nutrient content of Chino and Kaguno landraces from Jumla

Landrace	Polyphenol (mg/100g)	Flavonoid (mg/100g)	Tannin (mg/100g)	Antioxidant (% RSA)
Dude Chino	10.44	26.18	7.98	0.76
Haade Chino	13.83	25.08	6.69	3.03
Gumki Kaaguno	18.85	15.54	6.8	5.3
Seto Kaaguno	11.06	19.62	6.78	7.57
Raato Kaaguno	27.97	17.25	4.79	2.27

Table 7. District-wise significance different test on nutrient contents of proso millet and foxtail millet landraces

District	MSTR	CFa	TA	CP	CF	CHO	Fe	P	Ca
Proso millet									
Dolakha	7.76	7.71	7.74	7.84	13.38	68.95	2.84	17.69	121.96
Humla	9.55	7.84	7.60	9.29	13.90	61.60	2.05	42.21	127.08
Jumla	10.81	5.21	4.08	6.92	13.46	59.51	5.64	21.13	322.55
Average	**9.32**	**7.18**	**6.81**	**8.30**	**13.64**	**63.27**	**3.13**	**30.04**	**171.57**
p-value	0.0785	0.1506	0.0572	0.1370	0.9541	0.1392	0.0121	0.3741	0.1443
LSD, 0.05							2.2346		
CV, %	20.07	30.12	34.54	22.87	23.75	11.48	53.77	109.04	95.33
Foxtail millet									
Dolakha	7.84	7.79	7.87	7.86	12.90	68.64	1.87	19.12	115.04
Humla	8.25	7.03	6.59	7.54	15.66	67.81	1.79	28.16	63.58
Jumla	10.34	5.00	2.78	7.05	10.38	64.45	4.97	23.66	425.48
Average	**8.76**	**6.59**	**5.75**	**7.46**	**13.74**	**67.02**	**2.69**	**25.40**	**172.68**
p-value	0.1552	0.0985	0.0079	0.7636	0.0345	0.6108	0.0000	0.8656	0.0091
LSD, 0.05			3.0214		4.6450		1.2627		256.4190
CV, %	23.34	28.32	37.94	21.46	24.42	10.15	33.90	105.54	107.21

SN, Serial number; MSTR, moisture (%); CFa, crude fat (%); TA, total ash (%); CP, crude protein (%), CF, crude fiber (%); CHO, carbohydrate (%); Fe, iron (mg/100g); P, phosphorous (mg/100g); Ca, calcium (mg/100g). Samples of foxtail and proso millets from Dolakha are not originally collected from Dolakha and their origin places are not known.

The clustering of 54 landraces of proso millet, foxtail millet, finger millet, amaranth, bean, rice, sorghum, buckwheat and quinoa generated 7 clusters (**Table** 8). Cluster III has included the maximum number of landraces followed by cluster VI. The mean values of calcium and iron of cluster I were the highest. The highest mean value of crude fiber was in cluster II. Cluster IV had the highest mean value for carbohydrate. Cluster V had the highest mean value for fat and ash. Cluster VII had the highest mean values for protein and phosphorous. Most of the landraces clustered together based on the crop species (**Figure** 3). Quinoa was separated from others. Thulo Pahenlo and Khairo Simee were found similar. Kaalo Musuro and Raato Junelo were found closer to amaranth landraces. Foxtail millet and proso millet scattered in different clusters and have shown some similarity.

Table 8. Average nutrient value of each cluster of landraces shown in Figure 4

Nutrient	Cluster						
	I	II	III	IV	V	VI	VII
Cluster member, n	5	8	15	6	7	10	3
Moisture (%)	10.89	10.61	6.75	5.96	10.69	10.02	9.02
Crude fat (%)	4.58	5.20	6.72	6.11	10.67	1.83	6.67
Total ash (%)	3.35	3.28	6.71	5.82	10.69	2.53	3.90
Crude protein (%)	6.39	8.16	6.82	6.56	10.70	8.60	19.55
Crude fiber (%)	10.80	14.06	13.85	8.92	14.02	3.79	7.87
Carbohydrate (%)	63.98	58.70	72.99	74.12	57.25	73.23	53.00
Iron (mg/100g)	6.66	2.98	1.54	6.37	2.55	3.20	6.06
Phosphorous (mg/100g)	11.39	66.74	18.19	40.01	17.49	188.98	204.18
Calcium (mg/100g)	644.91	49.45	128.66	134.80	88.06	112.59	52.74

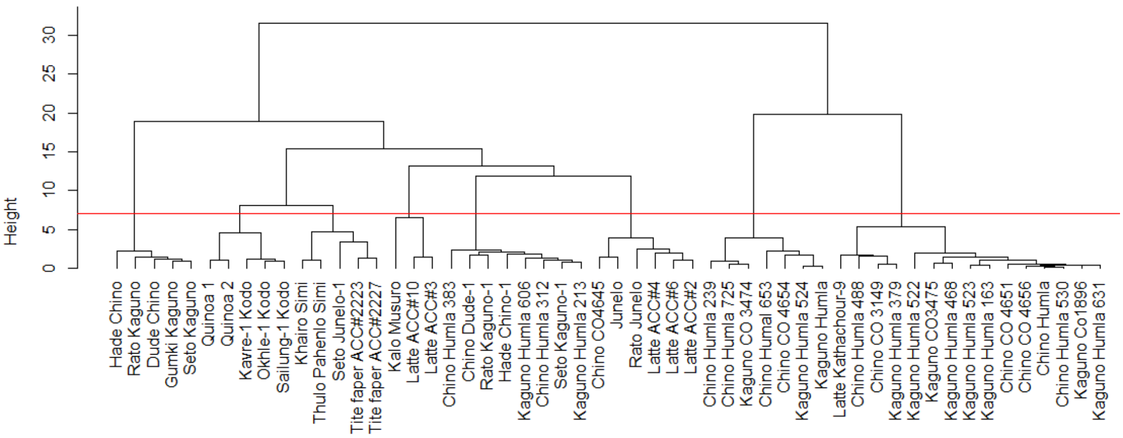

Figure 3. Clustering of 54 landraces collected from mountain areas, based on 9 different nutrient contents (see Table 3 for details of these landraces).

Three principal components explained 71% of variation for 9 nutrients in 54 crop landraces (**Table** 9). The higher contribution was of fat and ash in PC 1, of moisture and carbohydrate in PC 2 and of phosphorous and calcium in PC 3. Within a crop, landraces from the same district were plotted closer (**Figure** 3). Quinoa has fallen in third quadrant and has separated them from other landraces of different crop species.

Table 9. Eigen analysis and principal component (PC) coefficients based on 9 variables measured in 54 landraces collected from different districts of Nepal

Nutrient	PC1	PC2	PC3	PC4
Standard deviation	1.67	1.46	1.22	0.98
Proportion of variance	0.31	0.24	0.16	0.11
Cumulative proportion	0.31	0.55	0.71	0.82
Moisture (%)	-0.03	0.54	-0.09	0.53
Crude fat (%)	0.52	0.06	0.01	-0.06
Total ash (%)	0.53	-0.04	-0.01	-0.14
Crude protein (%)	0.04	0.49	0.25	-0.51
Crude fiber (%)	0.45	-0.07	-0.12	0.27
Carbohydrate (%)	-0.24	-0.60	0.07	-0.06
Iron (mg/100g)	-0.21	0.22	-0.49	-0.52
Phosphorous (mg/100g)	-0.35	0.22	0.38	0.24
Calcium (mg/100g)	-0.13	0.02	-0.73	0.19

Among the 77 landraces of proso millet, amaranth, bean, foxtail millet, finger millet, sorghum, buckwheat, rice, maize, wheat, quinoa, lentil, the landraces with the highest and the lowest nutrient contents are summarized in **Table** 10. Only 19 landraces were compared in case of polyphenol, flavonoid and antioxidant content.

Table 10. The highest and the lowest nutrient content landraces of different crop species

Nutrient	The highest amount		The second highest amount		The lowest amount	
	Landrace	Amount	Landrace	Amount	Landrace	Amount
Moisture (%)	Tite faper ACC#2227	13.38	Okhle-1 Kodo	13.29	Junelo	4.59
Crude fat (%)	Chino Humla 725	11.05	Chino CO 4654	10.85	Kaalo Musuro	0.2
Total ash (%)	Chino CO 4654	10.96	Chino Humla 725	10.85	Quinoa 1	0.45
Crude protein (%)	Sthaaniya Kaalo	33.76	Laamo Simee	32.29	Haade Chino-1	4.51
Crude fiber (%)	Kaaguno Humla 522	21.56	Kaalo kaaguno	19.64	LPNBR 1632 rice	0.86
Carbohydrate (%)	Quinoa 1	84.61	Quinoa 2	84.18	Latte ACC#3	49.91
Iron (mg/100g)	Latte ACC#4	9.16	Ghiu Simee	9.07	Hansaraaj Dhaan	0.4
Phosphorous (mg/100g)	Ghiu Simee	711.8	Asaare Simee	690.74	Kaalo Musuro	0.46
Calcium (mg/100g)	Gumki Kaaguno	752.27	Seto Kaaguno	706.28	Latte ACC#10	23.19
Polyphenol (mg/100g)	Sthaaniya Raato	320.5	Jumli Maarsee Dhaan	204.83	Asaare Simee	38.16
Flavonoid (mg/100g)	Raato kaaguno	131.9	Kaalo kaaguno	103.2	Asaare Simee	36.31
Antioxidant (%)	Sthaaniya Raato	92.99	Jumli Maarsee Dhaan	75.66	Kaalo kaaguno	15.12

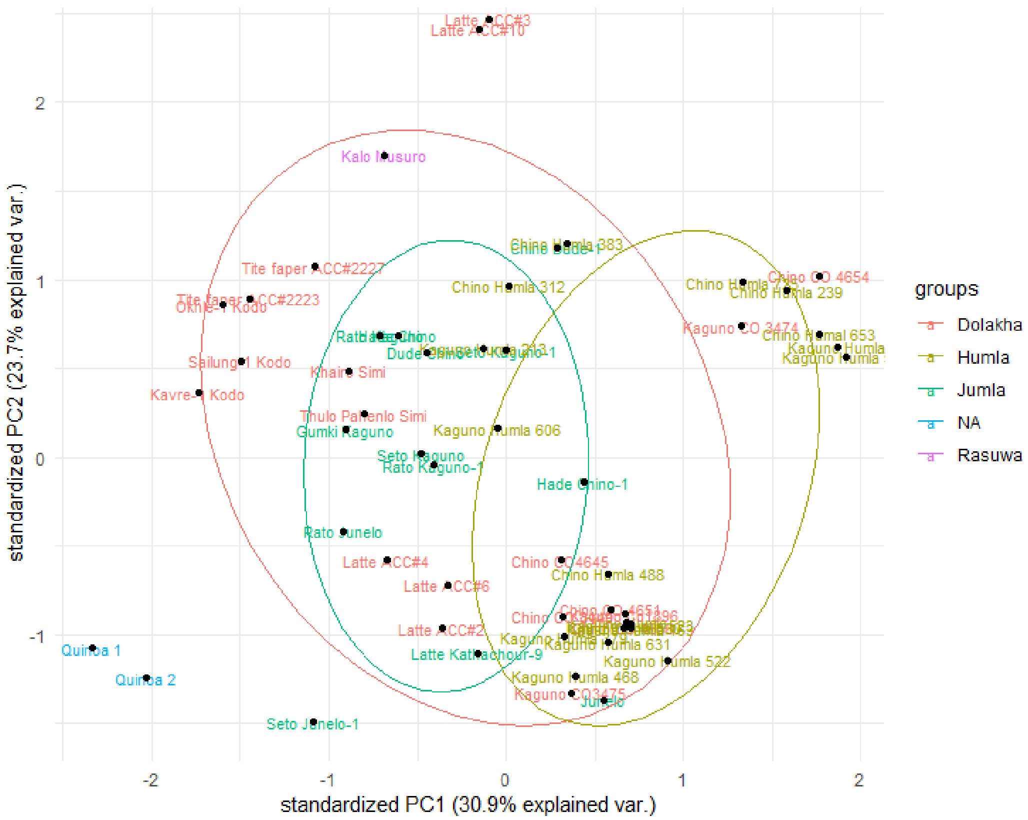

Figure 3. Plotting of 54 landraces of mountain crops based on nutrient contents using the first and second principal components (see Table 3 for detail of these landraces).

Current gaps and future opportunities

Marketing of localized products by the name of production areas is very common across the country for a large number of crop species, especially in the high and the mid hill areas. There are more than 100 agricultural products (Joshi et al 2017) which have already established their reputation representing their GIs. Malla and Shakya (2004) have identified and listed 87 potential products for geographical indication (GI) protection in Nepal. However, this system has not been legalized and information is poorly documented and system has not been regulated or monitored. Native crop landraces are nutrition rich and better for most of the nutrients in comparison with modern and introduced varieties.

Agricultural genetic erosion is estimated about 40% in Nepal (Joshi et al 2020) and there are many neglected localized landraces (Joshi and Adhikari 2019, Joshi et al 2019). One of the major factors of genetic erosion is favoring modern and introduced varieties or genotypes. GI cannot be granted to such introduced modern varieties. Many communities and farming groups are at risk of losing GI over native and localized genetic resources. Climate changes, chemical fertilizers and pesticides are also becoming challenging for getting GI. Only survey with growers and consumers can be considered as determinant factor for GI.

National Biodiversity Strategy and Action Plan (NBSAP) has recognized the policy and legislation gaps on geographical indication (MoFSC 2014). To involve in International Initiatives on IPR, Nepal became the member of WIPO in 1997. Nepal became the Party of Paris Convention for the Protection of Industrial Property 1883. After becoming the member of WTO in 2004 it automatically became the party of Agreement on Trade related Aspects of Intellectual Property Rights (TRIPS). International Treaty on Plant Genetic Resources for Food and Agriculture and Multilateral System (ITPGRFA-MLS) Implementation Strategy and Action Plan (IMISAP) has also included GI to study and consider under conservation as one of the action plans and programs (MoAD 2015). The Industrial Policy 2067 BS and the Commerce Policy 2072 BS has mentioned the policy provisions for promoting Intellectual Property Rights. National Seed Policy 1999 has objective of conserving and maintaining the genetic characteristics of indigenous speciality seeds of Nepal and coordinating concerned organizations to protect the rights over them. Nepal formulated and promulgated the National Intellectual Property Right Policy 2073 BS. Geographical Indication has been given due importance in this policy. It has policies in identification and promotion of Geographical Indication, Intellectual Property linked genetic resources, biodiversity among others. There are many policy provisions to identify, promote and regulate the GI, among others GI has given a separate identification mark and the inherent quality of GI will be taken as Intellectual Property which will be untransferable rights.

GI can be protected in accordance with international treaties and national laws under a wide range of concepts eg *Sui generis* system (special regimes of local protection), using collective or certification marks and methods focusing on business practices, including administrative product approval schemes. Department of Industry under Ministry of Industry, Commerce and Supplies (MoICS) is the responsible body for granting GI in Nepal. Concern authority, eg communities, groups, local government, local organizations, etc with sufficient information need to apply for GI certification on their products.

General implementation process of GI

Based on the existing study methods, mechanism, experiences and knowledge base gained from this study, we have proposed general steps for generating evidences of agriculture products related to GI, application for GI and implementing GI in the country (**Figure** 4). We generated evidence-based information on field and market survey as well as laboratory research but could not able to carry out grow-out test and validate in other locations. We suggest that the potential materials might be tested in original location (GI region) as well in other similar production domains (non-GI region) to validate the geo-linked properties. Materials from other localities also need to include in the grow-out test. Information should be generated on agro-morphological traits, organoleptic tests, quality and nutritional test as well post-harvest processing and other appropriate tests, which need to be published along with identifying the GI coverage (Joshi and Gauchan 2020). Appropriate sign has to be developed for GI to apply in particular commodity referring to location with establishing a mechanism to monitor the GI uses and its branding. Sharing, feedback collections and publication before getting the GI are important not to raise any issues in the future.

If possible, further study at genetic level in combination with experimental studies in specific soil and climate conditions might be useful to identify the genes and traits associated with geo-location. Different kinds of markers-based analysis (morphological, biochemical or DNA) as well as soil and climatic analysis may be considered for this work.

CONCLUSIONS

Survey and nutrient analysis indicated that Jumli Simee (bean) and Jumli Maarsee (rice) possess geo-linked properties and therefore are potential for getting GI. There are other Maarsee rice landraces grown in high altitude areas other than Jumla, but quality of Jumli Maarsee is unique and differs from other Maarsee rice (Acharya 2019). There are other landraces as well in other districts associated with geo-location, based on the nutrient contents. None of the single landrace of these crop species has higher nutrient contents, therefore, mixture cultivation might be a good strategy to get more nutritious products. Many landraces are far better than modern varieties for all nutrients except carbohydrate. Amaranth, foxtail millet, finger millet, bean, and proso millet possess higher nutrient contents than rice, wheat, maize and quinoa. On the basis of polyphenol, flavonoid, and antioxidant activity, these traditional mountain crops can be considered as a source of healthy diet.

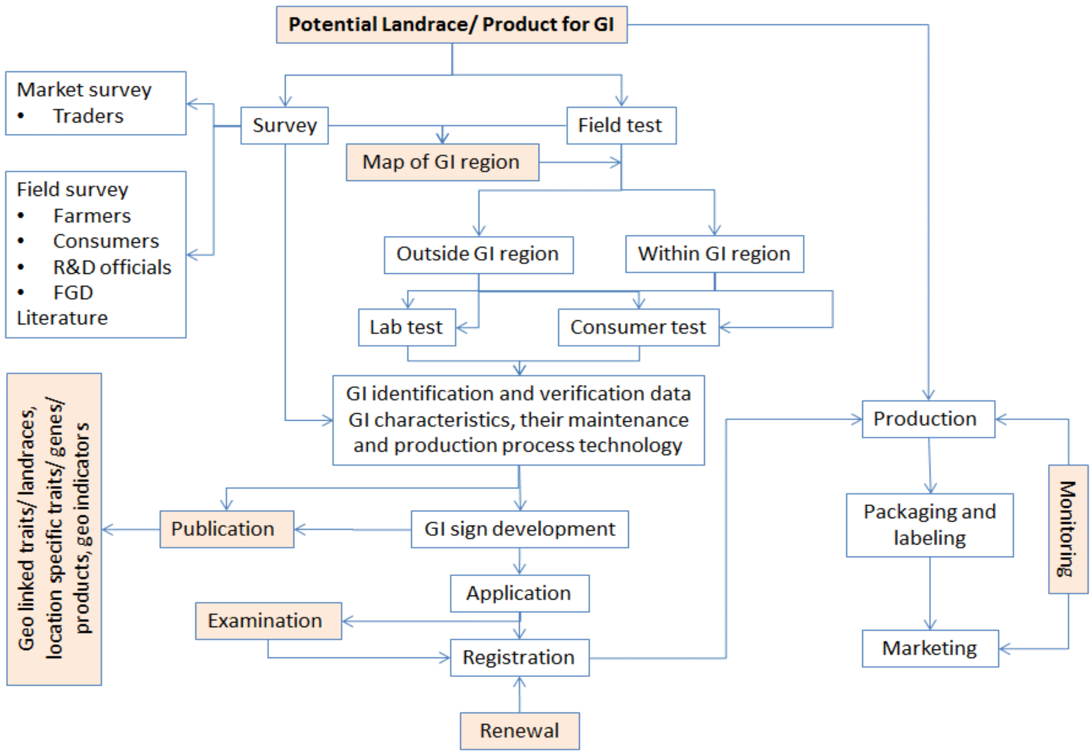

Figure 4. General process of generating information for getting geographical indication (GI) right and its implementation.

REFERENCES

Acharya PP. 2019. Jumli Maarsee Dhaan. Sambridhi Media Bizypan Agency, Kathmandu (in Nepali language).

Joshi BK and RC Adhikari. 2019. Economical Plant and Crop Species behind the Eyes of Researchers and Policy Makers. In: Working Groups of Agricultural Plant Genetic Resources (APGRs) in Nepal (BK Joshi and R Shrestha, eds). Proc National Workshop, 21-22 June 2018, Kathmandu; NAGRC, NARC, Nepal; **pp**.26-35.

Joshi BK, AK Acharya, D Gauchan, D Singh, KH Ghimire and BR Sthapit. 2017. Geographical indication: A tool for supporting on-farm conservation of crop landraces and for rural development. **In**: Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel; NAGRC, FDD, DoA and MoAD; Kathmandu, Nepal; **pp**.50-62.

Joshi BK and D Gauchan. 2020. Geographical indication. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu; **pp**. 35-39.

Joshi BK, NA Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 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 BK, R Shrestha, IP Gautam, AP Poudel and TP Gotame. 2019. Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Malla SB and PR Shakya. 2004. The Trips Agreement: Potential Products for Geographical Indications. for geographical indications. **In**: Selected Nepalese Agricultural Products for Geographical Indications agreement on TRIPS, Nepal; **pp**. 142-157.

MoAD. 2015. International Treaty on Plant Genetic Resources for Food and Agriculture and Multilateral System Implementation Strategy and Action Plan (IMISAP) 2015-2020. Ministry of Agricultural Development, Kathmandu.

MoFSC. 2014. Nepal Biodiversity Strategy and Action Plan 2014-2020. Ministry of Forests and Soil Conservation, Nepal.

MoICS. 2017. National Intellectual Property Policy. Ministry of Commerce, Kathmandu, Nepal.

Ojha P, S Raut, U Subedi and N Upadhaya. 2020. Study of Nutritional, Phytochemicals and Functional Properties of Mango Kernel Powder. Food Research Division, NARC, Khumaltar. Lalitpur.

WIPO. 2004. Geographical Indication: An Introduction. WIPO Publication No. 489 (E). World Intellectual Property Organization (WIPO), Geneva, Switzerland.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD and the Alliance of Bioversity International and CIAT.

Deploying Intra-specific Diversity of Traditional Crops in Mountain Agro-ecosystems through the Use of Climate Analogue Tool

Krishna Hari Ghimire, Bal Krishna Joshi and Devendra Gauchan

ABSTRACT

Mountain agriculture of Nepal is fragile and most vulnerable due to climate change effects. Farmers of this region grow portfolio of traditional crops mostly with their landraces, which are increasingly threatened by various pressures to grow exotic varieties and produce more food. Ex-situ collections of traditional crops available in the National Genebank are still beyond the easy access to the farmers of remote mountain areas. With the objective of deploying intra-specific diversity of traditional crops to mountain environments and improve varietal options to the farmers, different review work and field activities were conducted from 2015 to 2017. Climate Analogue Tool (CAT) was used to identify the climatically similar regions of four mountain sites namely- Chhipra (2,200 m) of Humla, Hanku (2500 m) of Jumla, Ghanpokhara (1550 m) of Lamjung and Jungu (1800 m) of Dolakha districts. A total of 2,175 accessions of eight traditional crops namely- amaranth, common bean, buckwheat, finger millet, foxtail millet, proso millet, naked barley and cold tolerant rice were conserved in the Genebank till 2014, while 855 accessions collected from the four mountain sites, rescue collection from affected districts in the aftermath of 2015 mega-earthquake and other similar environments were added to the collection. Intra-specific diversity of each crop collected from various analogous regions were deployed in each site and planted as diversity blocks during 2016. Highly significant correlation observed between climatic similarity of collection sites and grain yield at Chhipra, Humla for rice (r=0.90) and that at Ghanpokhara, Lamjung for finger millet (r=0.89). These results showed the reliability of CAT to be used for the sourcing and deployment of intra-specific diversity into the mountain agro-ecology. This tool can effectively be utilized to promote the use of diverse landraces of diversed crop species conserved in the Genebank.

Keywords: Climate analogue tool, climatic similarity, diversity block, grain yield, intra-specific diversity, landraces

INTRODUCTION

Nepalese farmers of mountain and hill agro-ecosystems mostly grow landraces or traditional varieties of most of the crops. Mountain agriculture of Nepal is challenging and most vulnerable due to the adverse effects of climate change. Farmers of this region are basically smallholders who grow portfolio of local crops mostly with their landraces that are increasingly threatened by various national and international pressures to grow genetically homogenous exotic varieties and produce more food (Ghimire et al 2020, Sthapit et al 2020). Genetic diversity in Nepal's traditional mountain crops (buckwheat, foxtail millet, prosomillet, naked barley and amaranth) are limited to a few varieties at the community level so farmers have limited options for selection (Gurung et al 2016, Palikhey et al 2017, Parajuli et al 2017, Pudasaini et al 2016). A portfolio of varieties exists in National Agricultural Genetic Resources Centre (the Genebank) and many research stations that include different varieties which are better than those currently grown by farmers but the ex-situ collections of local crops available in Genebank are still beyond the easy access of the farmers of remote mountain areas. Farmers have fewer options available to choose, especially at a time when more diversity is needed to cope with climate and market change (Atlin et al 2017). Crop genetic diversity can make farming systems more resilient, but a major constraint is that farmers lack access to crop genetic resources (Tripp 1997). Farmers need a genetically diverse portfolio of crop varieties suited to a range of agro-ecosystems. Crop diversity is the foundation for resilient production systems that can cope with climate-caused stresses like drought. Potential local landraces collected from different environments need to be deployed to the farmers of similar environments for enhancing timely access of the seeds to farmers.

Climate change is one of the most pressing challenges facing by the world; it has already had a profound impact on plant genetic resources (PGRs) and the livelihoods of people, mainly smallholders living in marginal environments (FAO 2011). Climate change may render locally available PGRs inadequate, thus underscoring the importance of access to other PGR sources (Esquinas Alcazar 2005, Fujisaka et al 2011). Nepal is a highly vulnerable country to climate change. Change in rainfall patterns, incidence of frequent droughts, floods and heat waves are major risks for agriculture in the country. Farmers will have to adapt to their new circumstances (drought, cold, flood, landslides, diseases and insect outbreaks, etc) as quickly as possible. This will particularly difficult for smallholders who completely depend on agriculture for their food and livelihood. Climate change has greatly affected the global crop production by favoring not only the abiotic stresses but also many biotic constraints like insects and diseases. The use of local and indigenous crops genetic resources is safer and cheaper way to cope with these challenges due to their better adaptation to local circumstances.

Climate Analogue Tool (CAT) is an open-access tool developed by the program on Climate Change, Agriculture and Food Security (CCAFS) in conjunction with the International Center for Tropical Agriculture (CIAT) and the Walker Institute (Ramirez-Villegas et al 2011). The tool can be used to identify future climate conditions at a particular locations and sites that currently resemble these conditions, and locations that have or will have similar climate conditions. Based on careful analyses using the tool and data from actual conditions in farmers' fields, scientists can formulate possible intervention strategies, including identification of appropriate PGRs or development of new varieties for specific locations of interest (Vernooy et al 2015, Joshi et al 2017c, Joshi et al 2020a), repatriation (Joshi et al 2020b), gap analysis and management of PGRs (Joshi et al 2008a, 2008b). However, efforts to address climate change remain a major challenge in developing and underdeveloped countries with large numbers of smallholder farmers. CAT takes climate and rainfall predictions for a particular site and searches for places with similar conditions at present. Comparing present day farming systems to their future analogues can facilitate the exchange of genetic materials with associated knowledge between farmers in different locations who shares common climatic conditions and allows adaptation strategies and technologies to be tested and validated. CAT can identify geographic areas with similar climatic conditions in past, current and future years, leading to the possibility of finding and exchanging suitably adapted germplasm. CAT uses three climate models: FORWARD (where can I find my site in future), BACKWARD (where can I find my place that currently looks like how my site would be in the future) and NO-DIRECTION (where can I find similar areas to my site currently). Major target of CAT is to identify analogue sites of any location at current and future, so that climatically related technologies including germplasm can be exchanged and introduced (Joshi et al 2017a). It has been used globally to identify the diversity risk zones due to climate change and to collect, conserve and deploy endangered genetic resources wherever necessary (Chaudhary et al 2016, Poudyal et al 2017, Joshi et al 2017a). Using CAT, current and future analogue regions of mountain sites can be identified suggesting that genetic materials could be exchanged with these sites. This paper highlights the status of intra-specific diversity of local crops in the Genebank and verifies the applicability of CAT to identify the climatically analogous areas and deploy potential landraces in four mountain sites of Nepal.

MATERIALS AND METHODS

Target crops and sites

This research was targeted for eight traditional mountain crops namely amaranth [*Amaranthus caudatus* L.*, A. cruentus* L. *and A hypochondriacus* L.], common bean [*Phaseolus vulgaris* L.], buckwheat [*Fagopyrum esculentum* Moench. and *F. atrium* (L.) Gareth.], finger millet [*Leucine coracan a* (L.) Geert.], foxtail millet [*Set aria italic a* (L.) P. Beaus.], naked barley [*Haredim vulgare* var. *nudum* (L.) Hook.], proso millet [*Panicum Mediacom* L.] and high-altitude rice [*Oryza sativa* L.]. Details of four mountain sites where intra-specific diversity of above crops was deployed, has been presented in Table 1.

Table 1. Geographic and climatic information of the experimental locations

Location	Geo-reference			Climate	
	Latitude (N)	Longitude (E)	Altitude (mall)	Average temperature range (ºrc)	Annual rainfall (mm)
Chiura, Humza	29.941º	81.853º	2200	0-20	50
Hanke, Jumla	29.232º	82.095º	2500	2-22	729
Ghanpokhara, Lamjung	28.306º	84.324º	1550	15-27	2944
Jungu, Dolakha	27.678º	86.189º	1800	4-22	2000

Source: Ghimire et al 2019.

Mapping intra-specific diversity

Genebank passport data of above-mentioned local crops were assessed and collection sites of all the accessions were mapped using geo-reference information (latitude and longitude) with the help of DIVA-GIS software (www.diva-gis.org). Missing geo-reference were extracted and updated from Google search engines: Google map (www.google.com/maps) and Google earth (www.google.com/earth). Released and promising varieties of mandate crops were also mapped according to their suitability in different agro-climatic regions. Collection gaps were identified after generating collection maps. Additional diversities of these crops were added to the Genebank by various collection missions during 2015-1016, mainly: i) diversity fairs in above four sites, ii) germplasm rescue missions from 10 mostly affected districts in the aftermath of 2015 mega earthquake (Gorkha, Lamjung, Dhading, Nuwakot, Rasuwa, Kavre, Makwanpur, Sindhupalchok, Dolakha and Ramechhap), and iii) other collections from the locations where collection gaps existed.

Finding analogue sites

CAT software was used to identify analogue sites ie sites with similar agro-ecological environment of four mountain agroecosystems using latitude and longitude in degree decimal format (**Table** 1). Among the three climate models such as Forward, Backward and No-direction, we selected non-directional model to find climatically similar areas of our four mountain sites at current climate. Separate analysis was run by setting temperatures and rainfall at equal weightage for the growing months of each crops. Climatic data from November to April were used for naked barley, whereas for other crops, climatic data from May to October were used based on the cropping seasons of the respective crops. Collection maps of each crop were overlaid into the analogue maps of each site to identify suitable landraces of these local crops for the respective sites.

Deploying diversity

Local landraces and released varieties available in the Genebank collected from similar climates were selected for each crop and deployed to four mountain sites. Selected entries including Genebank collections, landraces, released varieties and pipeline varieties of each crop were evaluated in diversity blocks during 2016 cropping seasons. There were eight diversity blocks in each site (one for each crop) and 32 diversity blocks or experiments in total. Different agro-morphological data were recorded for each crop by using their respective descriptors. Intra-specific diversity in each crop species was assessed based on morphological data.

Correlation and regression analysis

Among the large data from 32 experiments, correlation and regression analyses using MS Excel software were done randomly for two experiments ie rice at Humla and finger millet at Lamjung. Diversity blocks of 44 rice accessions and 52 finger millet accessions collected from different parts of the country were established at Chhipra and Ghanpokhara, respectively. Climatic similarity level (CSL) of each rice and finger millet accessions was obtained from the map of analogue sites of both locations. Correlation and regression between CSL and rice yield at Chhipra and CSL and finger millet yield at Ghanpokhara were done. The simple linear regression model used was: $y = \beta_1 x + \beta_0$; Where, y = response or dependent variable ie grain yield (kg/ha); β_1 = un-standardized coefficient for each predictor variables (slope); x = independent variable ie CSL and β_0 = constant (intercept).

RESULTS AND DISCUSSION

Mapping genebank accessions

Mapping of intra-specific diversity of eight traditional crops was done in 2014. Among the 2,175 accessions of eight mountain crops conserved in the Genebank, 429 accessions were from four project districts. The highest number of collection was from Dolakha district (162 accessions) followed by Jumla (157 accessions), Lamjung (60 accessions) and Humla (50 accessions) districts. All the eight traditional mountain crops were found in the collection from Jumla district only but proso millet in the collection from Dolakha, amaranth and buckwheat in the collection from Humla and amaranth and proso millet in the collection from Lamjung were absent. Table 2 showed the status of germplasm collections of traditional crops in the Genebank before and after the activity.

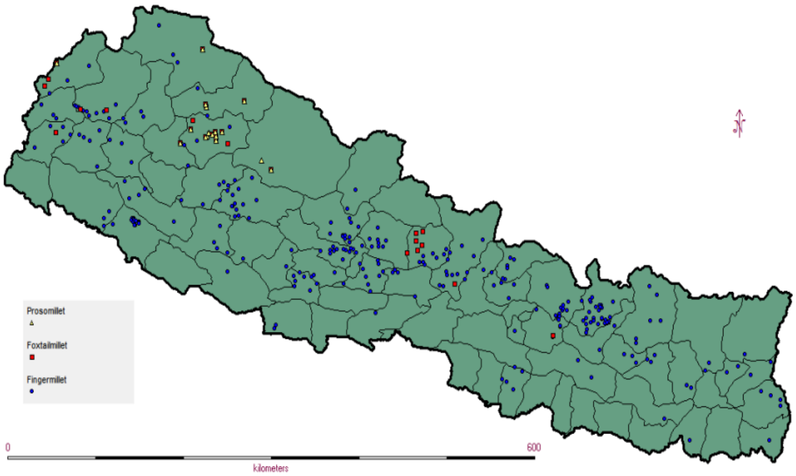

Figure 4. Mapping Genebank accessions of millets (finger millet, foxtail millet and proso millet).

Table 2. Status of germplasm collections of local crops in the Genebank during 2014 and 2017

Crop	Number of collections		
	2014	2017	Addition
Amaranth	76	248	172
Bean	430	465	35
Buckwheat	212	258	46
Finger millet	599	863	264
Foxtail millet	36	55	19
Naked barley	124	337	213
Proso millet	32	52	20
Cold tolerant rice	666	752	86
Total	2175	3030	855

Collection sites of all studied crops were plotted in the map based on their geo-coordinates. Figure 1 shows the collection sites of 3 different millet species (finger millet, foxtail millet and proso millet). Finger millet accessions were collected from across the country whereas proso millet accessions were from only Karnali regions and foxtail millet accessions were from western, mid-western and far-western high hills. Similarly, collections of buckwheat and naked barley and that of cold tolerant rice were observed from across the mid to high mountains of the country (Figure 2 and 3). Collection gap was observed in eastern part of the country for amaranth and bean (Figure 2). Among the eight targeted crops of the project, only six and five varieties have been released so far for high altitude (cold tolerant) rice and finger millet whereas only two for bean and one each for buckwheat and naked barley (Joshi et al 2017b).

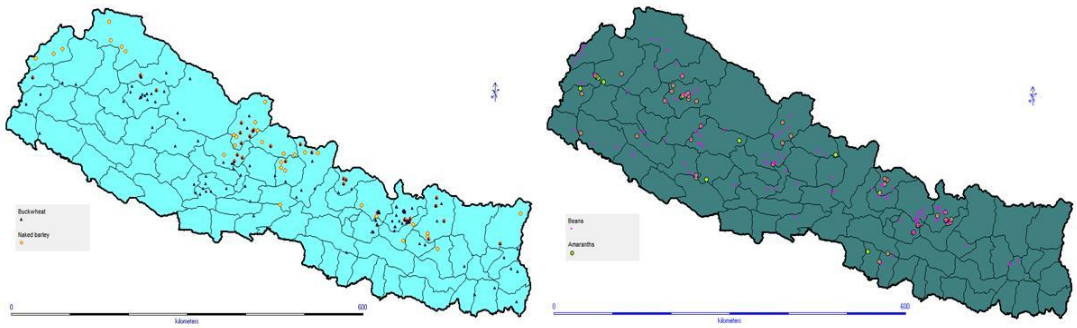

Figure 2. Mapping Genebank accessions of buckwheat and naked barley (left), amaranth and bean (right).

Identification of analogue sites

Collection map of cold tolerant rice was overlaid to the analogue map of Chhipra (Figure 3, left). Few accessions of cold tolerant rice collected from mid and far western high mountains were found suitable to deploy in Chhipra, Humla high mountain (2200-2500 msl).

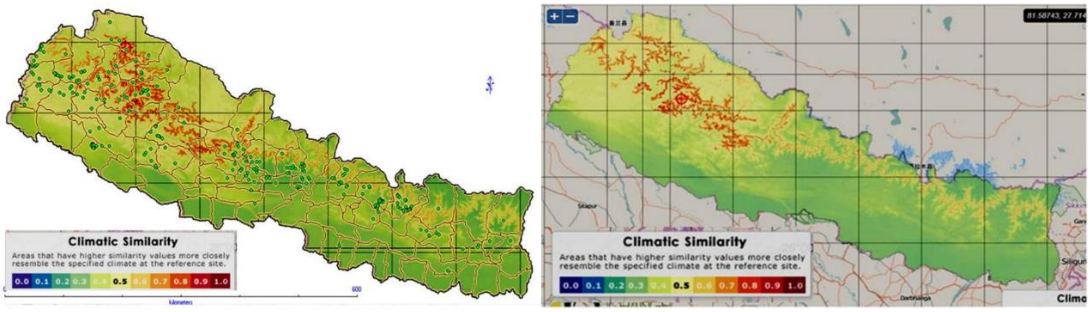

Figure 3. Rice collections in NAGRC overlaid with analogue sites of Chhipra, Humla based on temperature and precipitation data (current climate) from May to October ie rice growing season (left) and analogue site of Hanku based on temperature and precipitation data (current climate) from May to October (right).

Similarly, the analogue map of Hanku is presented in Figure 3 (right), whereas of that of Jungu, Dolakha and Ghanpokhara, Lamjung are presented in Figure 4. The map shows that Hanku has its analogous sites in higher mountains of mid to far western region. In contrast, the analogue sites of Jungu and Ghanpokhara are almost similar to each other, showing climatically matching sites from eastern to western mid mountains.

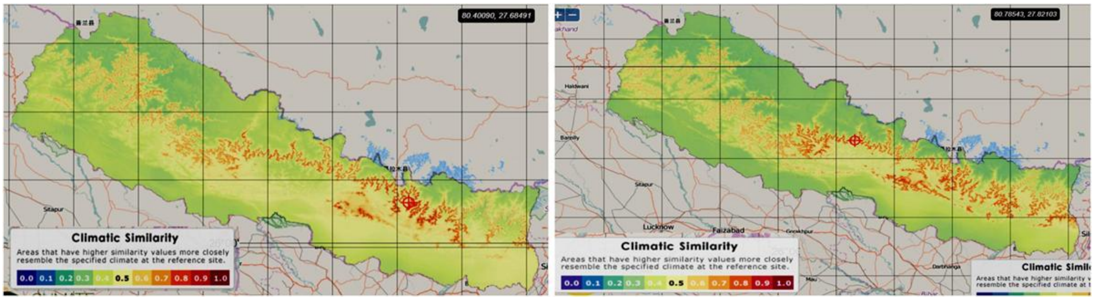

Figure 4. Analogue sites of Jugu (left) and Ghanpokhara (right) based on temperature and precipitation data (current climate) from May to October.

Diversity deployment

Genebank accessions of all mandate crops collected from eastern to far-western mid and high mountains were deployed into the four project sites by means of diversity blocks (Table 3). Out of more than 300 Genebank accessions (279 in Jumla, 243 in Humla and 225 each in Lamjung and Dolakha) deployed, more than 50 accessions each were of rice and finger millet. Diversity within the target crops species was assessed based on morphological data. The result revealed that there is very high intra-specific diversity exists in rice (Yadav et al 2019), finger millet (Yadav et al 2018b), foxtail millet (Ghimire et al 2018, Yadav et al 2018a), naked barley (Yadav et al 2018c) and common bean but medium to low level of intra-specific diversity was observed in proso millet (Ghimire et al 2017) and buckwheat. Inter-specific as well intra-specific diversity was observed at intermediate level for amaranth.

The agronomic performance of deployed landraces suggested that landraces from Karnali zone are adapted and suited to Chhipra (Humla) and Hanku (Jumla) sites only whereas the landraces from central and western regions are not suited to Karnali zone but suited to Ghanpokhara (Lamjung) and Jungu (Dolakha) sites. For example, a rice landrace, *Borang dhan* collected from Rasuwa (central mountain I) did well at Lamjung and now popular among the farmers due to the higher grain and straw yield, cold tolerance and good cooking quality. Similarly, the rice landraces collected from western mountains like *Chhomrong, Silange, Darmali, Kaalo Patle,* etc performed very poor in Humla and Jumla. In contrast, they performed well in Lamjung and Dolakha sites. Accessions adapted to Karnali region like *Jumli Maarsee* (rice from Jumla), *Kali Maarsee* (rice from Humla), *Raato Kodo* (finger millet from Jumla), *Kaalo Kaaguno* (foxtail millet from Humla) etc were performed very poorly in Dolakha and Lamjung. Similarly, released varieties of finger millets and Genebank accessions collected from eastern to western mountains of the country were performed worse at Jumla and Humla compared to *Raato Kodo* (finger millet landrace from Jumla) and *Tyase Kodo* (finger millet landrace from Humla). Similar results were observed in rice and other crops as well.

Table 3. Number of accessions deployed into the project sites through diversity blocks, 2016

SN	Crops	Humla	Jumla	Dolakha	Lamjung
1	Cold tolerant rice	44	60	69	62
2	Finger millet	53	53	26	52
3	Proso millet	22	22	21	12
4	Foxtail millet	23	27	28	20
5	Naked barley	20	20	24	20
6	Buckwheat	23	23	23	23
7	Amaranth	24	40	10	10
8	Common bean	34	34	34	34
	Total	243	279	225	225

Correlation and regression analysis

The grain yield of rice in the diversity block at Chhipra (Humla) had strong positive correlation (r = 0.90) with the climatic similarity level (CSL) of collection sites with respect to Chhipra. The predicted linear regression line displayed upward slope ie y = 3549.5x - 674.5; where 'y' denoted predicted grain yield of rice at Chhipra, and 'x' stood for CSL. The estimated regression line indicated that the 10% increase in the similarity level, the possibilities of yield increase existed by 287.5 kg/ha, with regression coefficient R^2 = 0.80 that means 80% of the variation was explained by the regression model (**Figure 5**).

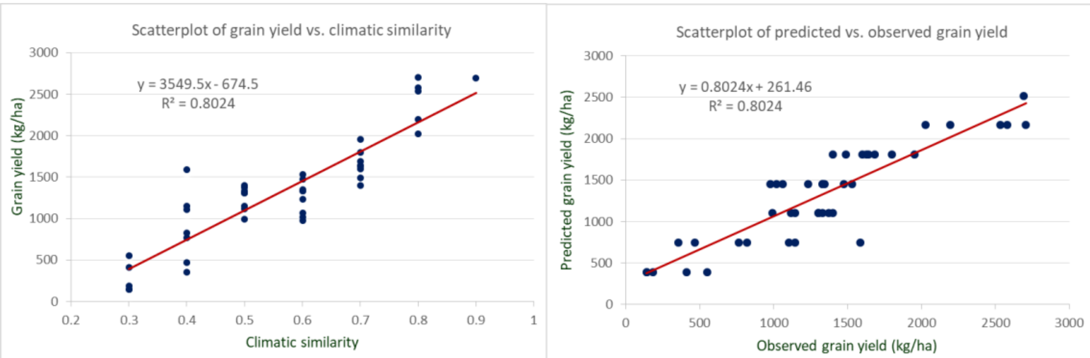

Figure 5. Scatterplot of rice grain yield versus climatic similarity (left) and predicted versus observed grain yield (right) in diversity block of 44 rice accessions at Chhipra, Humla.

Similarly, the grain yield of finger millet in the diversity block at Ghanpokhara (Lamjung) had significant positive correlation (r = 0.89) with the CSL of collection sites with respect to Ghanpokhara, Lamjung. The predicted linear regression line was displayed upward slope ie y = 3892.2x - 1263; where 'y' denotes predicted grain yield of finger millet at Ghanpokhara, and 'x' stood for CSL. The estimated regression line indicated that the 10% increase in the similarity level, the possibilities of yield increase of finger millet existed by 262.9 kg/ha, with regression coefficient R^2 = 0.79 that means 79% of the variation was explained by the regression model (**Figure 6**). Both the regressions revealed that higher the CSL of collecting sites, more will be the grain yield of that particular accession in a particular site which suggests the effective use of CAT for identifying analogue sites and selecting potential landraces for the deployment of intra-specific diversity in mountain regions.

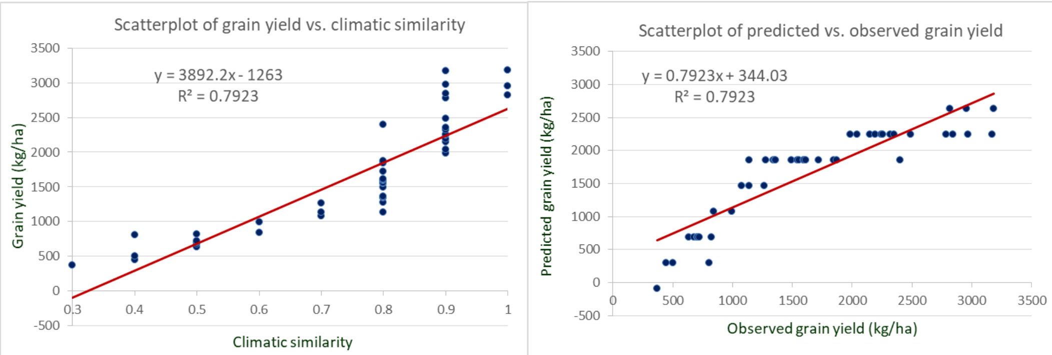

Figure 6. Scatterplot of finger millet grain yield versus climatic similarity (left) and predicted versus observed grain yield (right) in diversity block of 52 finger millet accessions at Ghanpokhara, Lamjung.

CONCLUSIONS

The highest intra-specific diversity in the Genebank collections was found in cold tolerant (high altitude) rice followed by finger millet, bean and amaranth whereas lower level of intra-specific diversity was observed for buckwheat and proso millet. More than 3000 accessions of eight traditional mountain crops namely - amaranth, common bean, buckwheat, finger millet, foxtail millet, proso millet, naked barley and cold tolerant rice were conserved in the Genebank sourced by various means like diversity fairs, rescue collection after 2015 mega-earthquake and other similar environments. The accessions collected from the districts analogous sites performed better in the target mountain sites compared to the accessions collected from non-analogous sites. This suggested that there are location specific landraces of target mountain crops for varied temperature and precipitation regimes. Highly significant correlation observed between climatic similarity of collection sites and grain yield suggested the reliability of CAT to be used for the sourcing and deployment of intra-specific diversity into the mountain agro-ecology. This tool can effectively be utilized to promote the use of diverse landraces of local crop species conserved in the Genebank.

ACKNOWLEDGEMENTS

Technical supports of Surendra Shrestha, Ajaya Karkee, Santosh Sharma and Niru KC from the Genebank, Safal Khatiwada and Devra Jarvis from Bioversity International, Site officers and technicians of the project are highly appreciated.

REFERENCES

Atlin GN, JE Cairns and B Das. 2017. Rapid breeding and varietal replacement are critical to adaptation of cropping systems in the developing world to climate change. Global Food Security **12:**31-37.

Chaudhary P, BK Joshi, K Thapa, R Devkota, KH Ghimire, K Khadka, D Upadhya and R Vernooy. 2016. Interdependence on plant genetic resources in light of climate change. **In**: Implementing the International Treaty on Plant Genetic Resources for Food and Agriculture in Nepal: Achievements and Challenges (BK Joshi, P Chaudhary, D Upadhya and R Vernooy, eds). LIBIRD, Pokhara; NARC, MoAD, Kathmandu and Bioversity International, Rome; Nepal; **pp**. 65-80.

Esquinas-Alcazar J. 2005. Protecting crop genetic diversity for food security: political, ethical and technical challenges. Nature Reviews Genetics **6:**946-953.

FAO. 2011. Draft updated global plan of action for the conservation and sustainable utilization of plant genetic resources for food and agriculture. Food and Agriculture Organization of the United Nations (FAO), United Nations, Rome, Italy. Document CGRFA/WG-PGR-5/11/2 Rev 1.

Fujisaka S, D Williams and M Halewood. 2011. The impact of climate changes on countries' interdependence on genetic resources for food and agriculture. Background study paper 48. Food and Agriculture Organization, Rome, Italy.

Ghimire KH, BK Joshi, R Gurung, E Palikhey, N Pudasaini and A Parajuli. 2019. Adaptability of naked barley landraces in mountain agro-ecosystem of Nepal. Journal of Nepal Agricultural Research Council **5**:34-42. **DOI**: https://doi.org/10.3126/jnarc.v5i1.22064.

Ghimire KH, BK Joshi, R Gurung, N Pudasaini, D Gauchan, S Sthapit and D Jarvis. 2020. Diversifying the sourcing and deploying methods to enhance the crop diversity. **In:** Good practices for agro-biodiversity management (BK Joshi, HB KC and AK Acharya, eds). NAGRC, LIBIRD and the Alliance of Bioversity International and CIAT, Kathmandu, Nepal.

Ghimire KH, BK Joshi, R Dhakal and BR Sthapit. 2017. Diversity in proso millet (*Panicum miliaceum* L.) landraces collected from Himalayan Mountains of Nepal. Genet. Resour. Crop Evol. **DOI**: http://doi.org/10.1007/s10722-017-0548-7

Ghimire KH, BK Joshi, R Gurung and BR Sthapit. 2018. Nepalese foxtail millet genetic diversity revealed by morphological markers. Genet. Resour. Crop Evol. **DOI**: http://doi.org/10.1007/s10722-017-0602-5.

Gurung R, SR Sthapit, D Gauchan, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: Ghanpokhara, Lamjung. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara. LI-BIRD, NARC and Bioversity International.

Joshi BK, A Mudwari, DB Thapa, MP Upadhyay and MR Bhatta. 2008a. Selecting environmentally analogous areas for wheat variety recommendation using GIS. Journal of Plant Breeding **3**:31-36.

Joshi BK, D Singh, P Chaudhary, KH Ghimire and M Khanal. 2017a. Biotechnology, geographical information system and climate analog tool for management of APGRs. **In**: Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel; NAGRC, FDD, DoA and MoAD; Kathmandu, Nepal; **pp**. 50-62.

Joshi BK, DK Ayer, D Gauchan and D Jarvis. 2020a. Concept and rationale of evolutionary plant breeding and it's status in Nepal. Journal of Agriculture and Forestry University **4**: (in press).

Joshi BK, HB KC, MP Upadhyay, SR Gupta, BR Lu, PN Mathur and BR Sthapit. 2008b. Ex-situ and in-situ management of wild and weedy rice in Nepal using a geographical information system. Plant Genetic Resources Newsletter **155**:69-74. http://www.bioversityinternational.org/publications/pgrnewsletter/article.asp?lang=en&id_article=10&id_issue=155

Joshi BK, KH Ghimire, R Gurung and D Gauchan. 2020b. Germplasm rescue and repatriation. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**. 48-52.

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal and B Sthapit. 2017b. Released and promising crop varieties of mountain agriculture in Nepal (1959-2016). LIBIRD, Pokhara; NARC, Kathmandu and Bioversity International, Pokhara, Nepal. http://himalayancrops.org/project/ released-and-promising-crop-varieties-for-mountain-agriculture-in-nepal-1959-2016/.

Joshi BK, R Vernooy and P Chaudhary. 2017c. Crop interdependence, adaptation to climate change and the multilateral systems of access and benefit sharing: The case of Nepal. Indian Journal of Plant Genetic Resources **30**(3):210-217. **DOI**: https://doi.org/10.5958/0976-1926.2017.00026.2

Palikhey E, SR Sthapit, D Gauchan and BR Sthapit. 2017. Baseline Survey Report, Haku, Jumla, Pokhara: LI-BIRD, NARC, DOA and Bioversity International. http://himalayancrops.org/project/baseline-report-hanku-jumla/.

Parajuli A, A Subedi, SR Sthapit, D Gauchan, A Adhikari and BR Sthapit. 2017. Baseline Survey Report, Chhipra, Humla, Pokhara: LI-BIRD, NARC, DOA and Bioversity International.

Poudyal K, BK Joshi, D Gauchan, S Sapkota, KH Ghimire, DMS Dongol and NR Adhikari. 2017. Analogue sites of earthquake affected areas in Nepal for deployment of climate smart rice landraces. **In**: Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal (Bal K. Joshi and Devendra Gauchan, eds). Proceedings of Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, BI and Crop Trust; Nepal; **pp**. 78-88.

Pudasaini N, SR Sthapit, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: I. Jungu, Dolakha. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.

Ramirez-Villegas J, C Lau, AK Kohler, J Signer, A Jarvis, N Arnell, T Osborne and J Hooker. 2011. Climate Analogues: Finding tomorrow's agriculture today. Working paper 12. CGIAR Research Program on Climate Change, Agriculture and Food Security, Cali, Colombia.

Sthapit B, D Gauchan, S Sthapit, KH Ghimire, BK Joshi, PD Santis and DI Jarvis. 2020. Sourcing and deploying new crop varieties in mountain production systems. **In**: Farmers and plant breeding: current approaches and perspectives (OT Westengen and T Winge, eds). Abingdon, Oxon; New York; **pp**. 196-216.

Tripp R. 1997. New seed and old laws: regulatory reform and the diversification of national seed systems. London: Intermediate Technology Pub.

Vernooy R, G Otieno, G Bessette, C Fadda, J van de Gevel, M Halewood, P Mathur, S Mittra, P Rudebjer, J Steinke, B Sthapit, J van Etten and M van Zonneveld. 2015. A novel strategy to discover and use climate-adapted germplasm. Bioversity International, Rome, Italy.

Yadav RK, AR Adhikari, S Gautam, KH Ghimire and R Dhakal. 2018a. Diversity sourcing of foxtail millet through diversity assessment and on-farm evaluation. *Cogent Food and Agriculture* **4**(1):1-17.

Yadav RK, R Gurung, R Dhakal, AR Adhikari, S Gautam, KH Ghimire and BR Sthapit. 2019. On-farm diversity assessment and participatory varietal evaluation of cold tolerant rice in mid-hills of Nepal. J. Crop Sci. Biotech. **22**(5):403-414.

Yadav RK, R Gurung, R Dhakal, S Gautam, AR Adhikari, KH Ghimire and BR Sthapit. 2018b. On-farm diversity assessment and evaluation of finger millet genotypes in the mid-hills of Nepal. Journal of Aridland Agriculture **4**:07-12.

Yadav RK, S Gautam, E Palikhey, BK Joshi, KH Ghimire, R Gurung, AR Adhikari, N Pudasaini and R Dhakal. 2018c. Agro-morphological diversity of Nepalese naked barley landraces. Agric. & Food Secur. **7**:86.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds.). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Seed Systems of Traditional Crops in the Mountains of Nepal

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ABSTRACT

Seed is a key input in agriculture system. Availability of preferred quality seeds at right time to farming community is important in maintaining productivity and ensuring food security of the people. The seed system must function properly for fulfilling required and preferred variety seeds at right time to farmers in affordable price. Periodic analysis of the seed system helps to identify and fulfill existing gaps. The Nepalese mountain farming system is managing large number of crops and varietal diversity and largely depends on them for food and nutritional security. However, there are limited or no scientific and systemic studies of the status of the seed system of the traditional underutilized crops in the high mountains of Nepal. Thus, this study is aimed to analyze the seed system of traditional mountain crops of Nepal so that possible set of interventions can be identified and suggested. Status of local seed system of 8 traditional crops was generated from survey of 328 households, supplemented with 8 focus group discussions, and field observations across four mountain sites (Humla, Jumla, Lamjung and Dolakha) of Nepal. Findings from the study revealed that 95% households depend on informal system where 83% of the households manage seed from own saved seeds, 10% from exchange between neighbors and 2% from relatives as gifts. Variation was found between crops, where 100% seeds of proso millet, foxtail millet and amaranth and over 97% for buckwheat, beans and naked-barley and 90% of the seeds of high-altitude rice were derived from farmers' informal seed system. Presently farming communities have limited knowledge and skills in seed selection, processing and storage which need to be improved through targeted interventions. Interventions include strengthening of local seed system by carrying out research and development work on the traditional mountain crops focusing on community seed banks and other community based approaches to promote linkage with formal seed system.

Keywords: Informal seed systems, seed management practices, traditional high-altitude crops

INTRODUCTION

Seed is one of the key inputs in agriculture production and ensuring food and nutrition security of the growing populations. The seed system generally have important functions for making healthy seed of preferred variety available at right time under reasonable conditions (Weltzien and vom Brocke 2001). Healthy seed system in place ensures the timely and quality seed availability which is critical to enhance productivity and resilience of the food production system of the farming communities and countries. The Nepal Himalayas are the primary and secondary centers of diversity for rice, amaranths, barley, buckwheat, millets, and bean (Hawkes 1998, UNEP GEF 2013). The traditional mountain crops and their seed system are important in safeguarding food security of the region due to its unique and rich diversity which is of global importance. It plays an important role in promoting productivity and minimizing the risk of crop loss hence makes the system climate resilient.

Informal or farmers' seed system is a dominant form globally, particularly in developing countries, where 60-80% of the seeds on which smallholder farmers depends upon are derived from informal system that are saved and exchanged on-farm or obtained through community sharing systems or local markets (Vernooy et al 2016). For traditional and neglected and underutilized species (NUS) crops, the extent of informal seed system is still higher with over 90% of the seed requirements are met through farm-saved and community exchanged seeds in developing countries. A recent study in Ghanpokhara, Lamjung in the middle mountain of Nepal showed that informal seed system is a predominant form with all most 100% of the seed requirement in high altitude rice and finger millet was derived from farmers' own saving (Wyss et al 2018). In the purely informal system, seed quality and seed diversity are mostly low due to lack of access of diversity from outside the community. The current seed system of traditional mountain crops in the remote mountain agroecosystems is inefficient to ensure farmers' access to quality seeds of wide range of choice varieties and promoting diversity and seed innovation in seed value chain. Therefore, improvement of farmers seed system and linking it with formal sector is a good strategy for seed sector sustainability (Almekinders and Louwaars 2000). There is a need of a well-functioning holistic and pluralistic seed system that plays dynamic roles in sourcing and deploying new diversity, facilitating timely access to seeds to smallholder farmers at affordable price and promoting seed production, marketing, use and seed-based innovation (Gauchan 2019). This study is aimed at analyzing the status of the seed system of traditional mountain crops from the perspective of its functionality. In addition, it aims at identifying areas of gaps and possible intervention so that the relevant programs can be formulated and implemented for its sustainability.

Research questions

The study aims to answer the following research questions:

1. What are the characteristics of seed system of traditional mountain crops?
2. What types of interventions could be helpful to improvise existing seed system to improve productivity and conserve biodiversity of traditional mountain crops in the Nepal Himalayas?

Objectives

The broad objective of the study is to analyze the farmer's seed system of mountain crops and identify gaps for possible interventions of seed system improvement. The specific objectives of the study are as below:

1. Document the seed system of traditional mountain crops and its functions
2. Identify gaps from perspective of healthy seed system
3. Suggest possible intervention and pathways for seed system strengthening for supporting livelihood and conservation of agrobiodiversity in the mountains of Nepal.

METHODOLOGY

Analytical framework

The study is established on the analytical framework of the seed system based on four different process-oriented components suggested by Weltzien and vom Brocke (2010). Its four components are a) germplasm base, b) seed production and quality, c) seed availability and distribution and d) knowledge and information. This article draws its conclusion from the data collected from August 2014 to February 2015. The study is focused on analyzing seed system of eight major Himalayan local crops grown in the mountain area of Nepal (**Table** 1).

Table 1. Traditional mountain crops, their scientific and local names and genetics

Crop	Local names	Scientific name/synonym	Pollination	Genetics
Amaranth	*Latte, Marshe*	Amaranthus hypochondriacus A. caudatus A. cruentus	SP	2n=32 2n=34 2n=32
Barley	*Jau*	Hordeum vulgare	SP	2n=2x=16
Naked barley	*Uwa*	Hordeum vulgare var. nudum	SP	2n=2x=14
Bean	*Simee*	Phaseolus vulgaris	SP	2n=22
Buckwheat	*Phaapar*	Fagopyrum esculentum F. tataricum	CP SP	2n=2x=16 2n=2x=16
Finger millet	*Kodo*	Eleusine coracana	OS	2n=36
Foxtail millet	*Kaaguno*	Setaria italica	SP	2n=18
Proso Millet	*Chino*	Panicum miliaceum	SP	2n=36
Rice	*Dhaan*	Oryza sativa	SP	2n=2x=24

Selection of study sites

The study sites represent the middle mountain to the high mountain regions of Nepal representing from west to eastern four districts of Nepal, namely Humla, Jumla, Lamjung and Dolakha (**Figure** 1). From each district, one village development committee (VDC) was purposively selected based on the dominance of traditional crops. These include, Chhipra in Humla, Hanku in Jumla, Ghanpokhara in Lamjung and Jungu in Dolakha.

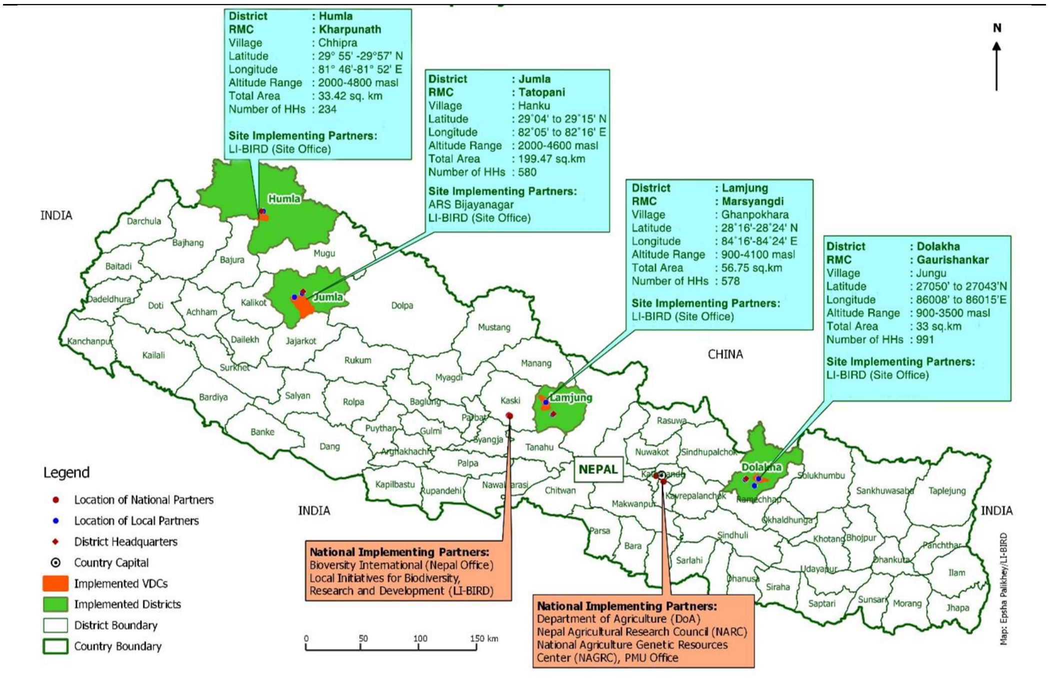

Figure 1. Map showing study areas in political map of Nepal.

Data collection methods

Key informant interview (KII)

A key informant interviews were conducted with key persons of the site on agriculture sector of the region with special focus on seed availability of target crops. The key informant includes the innovative farmer, governmental officials, agriculture development officer and local leaders of the study sites.

Focus group discussion (FGD)

A total of 8 group discussions were conducted, two group discussions in each of the four sites in 2015. Group discussions were conducted with mixed group of farmers to document seed management practices adopted by them. After the first series of group discussion in all sites and documenting information, a follow up group discussion was conducted with few selected custodian farmers who participated in the first group discussions to get additional information mainly on choice or portfolio of variety available to farmer to choose and outlet and organization available to choose seed from.

Baseline household survey (BHS)

Seed system of target crops and socio-economic conditions of the study site was documented from household questionnaire survey in 328 households [Chhipra, Humla (72), Hanku, Jumla (83), Ghanpokhara, Lamjung (83), and Jungu, Dolakha (90)]. The survey was held from December 2014 to February 2015.

Direct observations

The additional and supporting information were collected from participant observation and informal interaction with local farming community. Digital documentation was also done especially on traditional practices of farmer's seed management skills and equipment.

RESULTS AND DISCUSSION

Socio-economic characteristics of study sites

Table 2 presents site specific socioeconomic features of the study sites. Most of the households of study sites practice agriculture; with more than 40-50% households' major source of livelihood was agriculture in all sites. Remittance was recorded as one of the major sources in Ghanpokhara, Lamjung (30%) and Jungu, Dolakha (11%). Food sufficiency status ranges between 5 to 7 months on average across the sites with smaller farm size in Humla and Jumla compared to Lamjung and Dolakha (Gauchan et al 2020). In all sites, the decision making was jointly done in more than 50% households. In Jungu (38%) of Dolakha and Ghanpokhara (28%) of Lamjung had significant percentage of households where women alone make decisions. This can be attributed to the higher number of men migrants outside the village in search of employment making remittance as one of the major sources of income and livelihood.

Status of traditional crop diversity in study sites

The **Table** 2 below also presents status of crop diversity and seed system situation in the study sites. The diversity of traditional mountain crops was high with high number of landraces with highest number of crops and landraces in Chhipra, Humla. The predominance of informal seed system is high in all sites, where 83-97% of the seed requirements are met by farmers own saving and community exchanged seeds. This informal seed system was highest in Humla (97%).

Table 2. Site specific features of crop diversity, seed system, socioeconomic situations

Feature	Chhipra, Humla	Hanku, Jumla	Ghanpokhara, Lamjung	Jungu, Dolakha
Arable land	<10 %	40%	20%	40%
Mandate crop diversity	52 landraces of 8 crops	29 landraces of 8 crops	27 landraces of 7 crops	31 landraces of 6 crops
Dominant mandate crop (%HH, household)	Bean, amaranth, finger millet, proso millet (>80%)	Rice, bean and barley (>80%)	Rice (94%), finger millet (58%), bean (41%)	Finger millet (97%), bean (81%)
Farm-saved seed (%)	97%	87%	87%	83%
Agriculture as primary source of income	54% HHs	83% HHs	40% HHs	56%
Food sufficiency by own production (months)	4.67 ± 0.33	5.52 ± 0.33	7.18 ± 0.37	7.1 ± 0.3
Migration status (% HH)	4.1%	27%	71%	83%

Analysis of seed system

The data for analyzing seed system was collected on the basis of four major components: germplasm base, access/availability (seed source), and production of seed and associated practices and mechanism of getting information on seed/varieties.

Germplasm base: Richness and functional trait analysis

The count of number of varieties of the crop is the richness and is the measure of germplasm base. The study shows that varietal richness of traditional mountain crops at the household level is higher for rice, finger millet and bean but relatively lower for buckwheat, amaranth, prosomillet, foxtail millet and naked barley (**Table** 3). The varietal richness range of rice and finger is higher in Lamjung (24) and Dolakha (16) as compared to Humla (4) and Jumla (6). Rice and finger millet were among major crops grown by over 50% of the households in all the sites. In contrast, crops like proso millet and barley are only grown in Humla and Jumla. Buckwheat is also cultivated by significant number of households in Jungu, Dolakha. Apart from these cereal crops, bean is one of the major crops which is grown by more than 70% of households in Humla, Jumla and Dolakha.

Table 3. Number of local landraces and percent households growing crops in the study sites (2015/16)

Crop	Number of local landraces				% of household growing the crops			
	Chhipra	Hanku	Ghanpokhara	Jungu	Chhipra	Hanku	Ghanpokhara	Jungu
Amaranth	3	4	3	3	30	30	8	11
Barley	1	1	1	1	98	98	1	38
Bean	4	11(1)	9	11(2)	99	99	41	81
Buckwheat	2	3	1	2	20	20	4	36
Finger millet	4	3	14	12(3)	89	89	58	97
Foxtail millet	4	4	3	0	10	10	10	NA
Naked barley	4	0	1	1			1	7
Proso millet	3	2	0	0	89	5	NA	NA
Rice	4(1)	6(4)	24(1)	16(2)	58	100	50	70

The figure in parenthesis indicates number of released varieties in the seed network.

The data shows that the germplasm base of these high-altitude traditional mountain crops is composed of local landraces which highlights the importance of local landraces in seed system. In contrast, there is only one released variety of high-altitude rice in Chippra, Hanku (Chandannaath-1) and Chhomrong in Ghanpokhara, Lamjung. This highlights the lack of researches done on these mountain crops and production environments. Apart from rice, the community level richness in Jungu, Dolakha shows the presence of improved varieties of finger millet (Okhle, Kabre-2 and Dalle). Only one variety in barley and proso millet is available in the community though it is cultivated by more than 50% household in Chippra (Humla) and Hanku (Jumla). The amaranth is not cultivated widely in Ghanpokhara (Lamjung) and Jungu (Dolakha), though local landraces are found in the community.

Status of farmers' preferred traits and variety: Status, gap and relevant intervention

The seed system is also analyzed from the perspective of status of farmers' preferred traits in the varietal profile of the community. Across the sites, in all crops, higher yield and taste are the primary traits based on which farmers choose a variety. However, there is a site-specific difference in the variety selection criteria without compromising the yield and taste factors across the sites. In the case of rice, farmers generally cultivate more than one variety based on the land habitat. These practices are prevalent mainly in Lamjung and Dolakha where farmers have different land parcels at different altitudes that require varieties with different adaptations. In Jumla, though there is serious problem of blast in local landrace Jumli Maarsee, it is still the preferred variety for its preferred traits such as yield, taste and market price.

The data collected by focus group discussion show that the varietal range as per preferred traits is narrow, even in rice and finger millet. From the observations, farmers need better yielding variety with yield stability. There are those custodians and nodal farmers, who look for new varieties and test it beforehand. If the variety does well, other farmers will adopt it as they have seen the variety’s performance. This is one of the common ways of variety introduction and adoption in rural areas of Nepal.

Early maturity is the most preferred trait for barley and naked barley. As there are no early maturing varieties of naked barley available, farmers in Humla and Jumla are replacing naked barley with barley. Growing of naked barley was also associated with the food culture of particular ethnic community in Humla and Jumla. The Mugal family who cultivate this crop use it as *sattu* (roasted flour) for food and for making local liquor. But at present, this crop is not valued due to change in food habit. In Lamjung and Dolakha, bean is mainly cultivated for use as green vegetable and as grain in little amount. *Raato, Simkote Kaalo*, and *Malae* are selected for early maturity. In buckwheat, common buckwheat variety (*Mithe*) is preferred for taste but a greater number of farmers cultivate bitter variety (*Tite*) due to its high yield potential. In case of rice and finger millet, straw yield and quality with optimum grain yield are also considered while selecting variety.

The analysis showed the gap in terms of varietal options for barley, proso millet, and foxtail millet. Lack of varietal diversity in barley is surprising because it was grown by 98% of the households in some communities. On the other hand, proso millet and foxtail millet were grown by a small proportion of households in the community. Crops which have several landraces, there are no adequate number of varieties of preferred traits for farmers to choose. For increasing germplasm base of these crops, both in terms of number and farmers' preferred traits as per their socio-economic and ecological need, research studies and community’s collective action have to be interlinked. Testing Genebank accessions of the crops collected from similar agro-ecological zones and testing in the sites can be a method in analyzing and choosing better performing varieties. Selected varieties from the testing can be later distributed to local farmers by seed multiplication involving local farmers. For this holistic approach, community seed bank can be appropriate intervention.

Seed availability and its access

The baseline survey revealed that seed system of mandate crop is informal where farm-saved seed and social network (exchange between neighbor and relatives and getting seed as a gift from relatives residing in nearby villages) cover more than 95% of seed needs (**Figure** 2). In case of proso millet, foxtail millet and amaranth, the share of informal system is 100% as there were no formally released varieties.

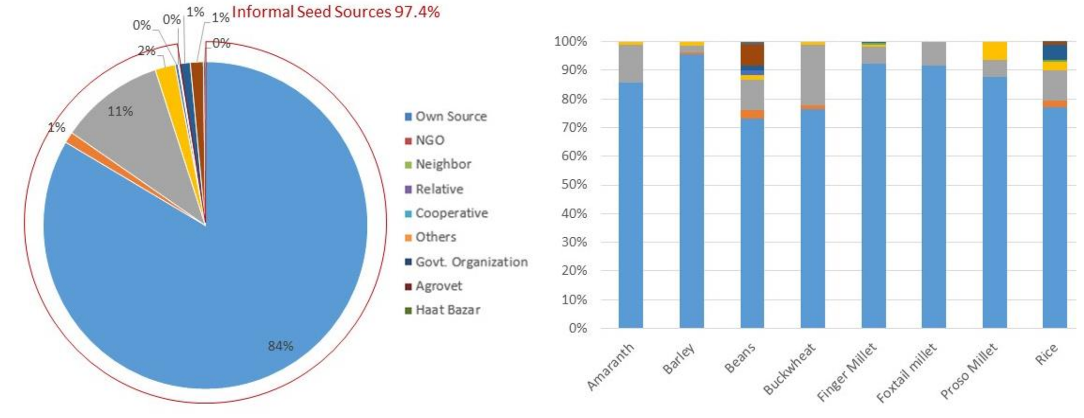

Figure 2. Seed source of traditional crops across the study sites.

This analysis showed that the seed system of this crop is informal and rudimentary in terms of access. There is no involvement of external and formal sector such as governmental organization and local formal market like seed dealer (agrovet), NGO and cooperative sector in making seed access to the farming community. Also, the geology and isolated mountain has limited the mobility and eventually hindered the easy access and exchange of seed among communities.

The research and development pattern of the crops shows that these mountain crops have been neglected and underutilized. There is no or minimal involvement of governmental and private organization in identifying, releasing better varieties, especially of proso millet, foxtail millet and even amaranth to farming communities from research. Seed companies and agrovets only sell released varieties of profitable crops. Unless, the seed is made available through diverse networks, mechanism with needed information, the seed system is not healthy in term of its performance. Diversification is needed not only in variety number but also in networks/system by which a farmer receives the seed. In process of diversifying seed source, various tools like participatory seed exchange, local market can be used. At the system level, the local landraces should be further evaluated and linked with national/formal seed system by registration and release process so that they can be promoted legally. The governmental and non-government organizations and private sectors (seed company, seed dealers and agrovet) can be mobilized in this process.

Quality seed production

This section deals with steps involved in quality seed production steps, its maintenance and storage. As the major portion of seed comes from farm-saved, the study tried to document the practices followed by farmers in managing seed at their farm level. Seed selection (either in the field or after harvest), harvesting, processing, cleaning, drying and storage are basic steps being followed by farmers. Seed selection, the key step in maintaining seed quality, is only done in the major crops such as rice and finger millet. Selection of panicle/ear of the largest seed from disease free plant is likely to contribute in maintaining seed vigor (Almekinders et al 1994). Other minor crops such as in barley, buckwheat, proso millet, amaranth seed selection activity is not performed seriously. Our observations suggest that farmers with low food sufficiency status and less landholding, generally do not do seed selection as the food crops is generally insufficient to feed themselves. Such farmers rather ask seed from custodians or resource rich farmers in planting season in return of agriculture labor as wage. The practice being followed by farmer in seed selection varied from farmer to farmer and all farmers may not have followed optimum practice. So, providing basic training on seed selection technique can be an area of intervention to enhance the quality of seed.

The other area of intervention can be storage equipment. If the seed is not stored properly, it damages the seed quality. The current practice is to use bottle or sacks for storing seeds without proper monitoring during storage. Seed storage materials such as super grain bag such as grain pro, Purdue improved crop storage (PIC) bags can be supported to the local community. These seed storage materials can be made available at 50% incentive price through the government system. These also can be especially beneficial to the local institution such as community seed banks where seed quantity is high.

At the community level, for making quality seed available to all farmers, a community collective action is needed, and community seed bank can be a better option in this scenario. The GEF UNEP Local Crop Project has therefore, established and operationalized community seed banks (CSBs) in all of the study sites of Humla, Jumla, Lamjung and Dolakha to strengthen local seed system, improve value chains of traditional mountain crops and conserve biodiversity for nutrition sensitive agriculture (Gauchan 2019). Registration and release of traditional mountain crop varieties are also most important to promote enhanced seed availability and dissemination in wider areas. Till date, only few traditional varieties of mountain crops are registered and released for making their seeds widely available (SQCC 2019).

Knowledge and information flow

Knowledge on any crops and varieties is needed to get full benefit of that crop. Whether it is planting season or the compatibility of the varieties in the farmer's field, it plays an important role in getting desired plant stand and eventually good production at the end of the planting season. Other information like from where the variety can be accessed and from where services are provided also play an important role.

Farmer to farmer information flow is the only available option for farmers on getting information on varieties they are planting. The baseline results showed that more than 90% of household of the community have not even heard of community seed bank (CSB), not even participated in farmers field school (FFS). The village is far from the nearby big market. That could be one reason why they were not connected. Also, there is almost no involvement of seed from formal sector like seed dealer (agorvet), government line agencies, local NGOs and cooperatives except in rice and bean (less than 2%).

The seed without proper information (time of planting, traits, characteristics, etc) may cause crop failure leading to loss. So, not only the quality aspect of seed, but also information about the seed is equally important. Awareness on importance of local landraces ie agrobiodiversity is another key area where farmers' awareness level should be increased. Various interventions can be designed of which CSB is the best one. The documentation and generating information on the characteristics and functional traits of local landraces are the important components that can be used to improve local seed system of CSB, so this is the most appropriate intervention used for strengthening local seed system (Gurung et al 2019). During the process, traditional knowledge and practices are also be preserved which add value to the local seed system as the local and formal seed system is complementary to each other.

CONCLUSIONS AND RECOMMENDATIONS

This study analyzed the seed system of 8 traditional mountain crops from four process-oriented components: germplasm base, seed production, access and associated information and knowledge which help to make the seed system healthy by fulfilling its basic function. This study documented present status of seed system of traditional high-altitude mountain crops and tried to suggest intervention based on gap analysis findings. The study findings showed that seed system of traditional mountain crops is informal in nature. It has both strengths and weaknesses. The local system, especially genetic base and associated traditional knowledge base are the strength which must be well documented for further research work. Farmers need analysis helps researcher to develop desired variety by using local diversity which is another benefit of local seed system. However, it is worth to note that genetic base or varietal portfolio for some crops such as barley, foxtail millet, proso millet are found to be low. So, there is scope for variety deployment and related researches for productivity improvement of the area. Hence, the formal and informal seed system is complementary to each other.

A great potential exists to increase crop productivity and income of resource poor farmers in marginal mountain environments by integrating formal and informal seed systems and strengthening existing mountain farming systems. Quality improvements in the local farmers' seed systems and its transformation and enhanced linkages with the formal seed systems and markets are critical to make effective functioning of seed system for the traditional mountain crops for increasing agricultural productivity and income of small famers (Gauchan 2019). Overall, to increase the germplasm base, making appropriate seed available to farming community a collective action at community level is needed in coordination with governmental agricultural agencies. The research and developmental sector should be interlinked. In this regard, community seed bank inclusive of research activity such as documenting and testing local landraces, identifying preferred varieties, linking with governmental sector can help to strengthen seed system. Capacity building of farming communities and stakeholders is important to strengthen local seed system and diversify production system linking with formal sector agencies. For further research and recommending site specific intervention, more rigorous study analyzing socio-economic dynamics on on-farm management of the crops and functioning of local seed system are needed to strengthen local seed system by linking with formal seed system.

ACKNOWLEDGEMENTS

The authors acknowledge the support of all the project team members particularly to the field staff of four project sites for their support in generating data for this study. We are very much thankful to late Dr. Bhuwon Ratna Sthapit, Bioversity International, Nepal office for his great insights and guidance in the initial development of this paper. Special thanks also go to Bharat Bhandari, Program Development Director, LI-BIRD for his initial inputs on the paper.

REFERENCES

Almekinders CJM and NP Louwaars. 2002. The importance of the farmers' seed systems in a functional national seed sector. Journal of new Seeds **4**(1-2):15-33.

Almekinders CJM, NP Louwaars, and GH De Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. Euphytica **78**(3):207-216.

Gauchan D. 2019. Seed sector development in Nepal: Opportunities and options for improvement. **In**: Agricultural Transformation in Nepal: Trends, Prospects, and Policy Options (G Thapa, A Kumar and PK Joshi, eds). International Food Policy Research Institute (IFPRI). Springer Singapore.

Gurung R, R Dhakal, N Pudasaini, PB Paneru, S Pant, AR Adhikari, S Gautam, RK Yadav, KH Ghimire, BK Joshi, D Gauchan, S Shrestha and DI Jarvis. 2019. Catalogue of Traditional Mountain Crop Landraces in Nepal. LI-BIRD, Pokhara, NARC, Kathmandu and Bioversity International, Nepal.

Gauchan D, BK Joshi, S Sthapit and D Jarvis. 2020. On-farm Diversity and Consumption Choices of Traditional Crops in the Mountains of Nepal. In: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Hawkes JG. 1998. Back to Vavilov: Why were plants domesticated in some areas and not in others? **In**: The Origins of Agriculture and Crop Domestication (AB Damania, J Valkoun, G Willcox and CQ Qualset, eds). Proceedings of Harlan Symposium. ICARDA, Aleppo. Syria; **pp**. 5-9.

SQCC. 2019. Notified Varieties of Crops in Nepal. Seed Quality Control Centre (SQCC), Ministry of Agriculture Development (MoAD), Pulchowk, Lalitpur, Nepal.

UNEP GEF. 2013. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in Nepal Himalayas. Project Document, United Nation Environment Program (UNEP), Global Environment Facility (GEF) and Bioversity International, Kathmandu, Nepal.

Vernooy R, G Bessette and P Rudebjer, eds. 2016. Resource box for resilient seed systems: handbook. Bioversity International, Rome, Italy. http://www.bioversityinternational.org/e-library /publications /detail/resource-box-for-resilient-seed-systems-handbook/

Weltzien E and vom Brocke K 2001. Seed systems and their potential for innovation: conceptual framework for analysis targeted seed aid and seed system interventions. **In**: Strengthening Small Farmers Seed Systems in East and Central Africa (L. Sperling, ed). Proceedings of a workshop held in Kampala, Uganda, 21-24 June 2000; **pp**. 9-15.

Wyss RI, López Noriega, D Gauchan and D Guenat. 2018. Farmers' access to quality and diverse seed in Nepal: Implications for seed sector development. Policy Research Brief. Bioversity International. Rome, Italy www.bioversityinterantional,org.

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Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Tradition of Mixing Bean Landraces: Diversity Rich Solution for Secured Quality Harvest and Conservation in Mountain Agriculture

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ABSTRACT

Bean mixture is very old tradition in mountain agriculture. Knowledge on status, reasons and advantages of mixing bean landraces help to improve the mixture practice and extend this method to other crops. We conducted 4 focus group discussions (2 males and 2 females separately) with farming communities of the selected two representative villages in each Jumla and Humla districts based on the different questionnaire related to bean mixture. Key informant surveys (KIS) were also conducted in both districts representing key stakeholders involved in production, marketing, and consumption including research and development. In KIS, we selected most knowledgeable farmers, traders, consumers and R & D officials involved in bean production, marketing, research, extension and consumption in these districts. Landraces mixture practices, a tradition, is only practiced in bean and passed from generation to generation. However, some farmers in Humla do mixture in amaranth and wheat. They consider same maturity period of landraces to be mixed during cultivation. In mixture, there were 4 to 9 different landraces of bean based on seed color and shape. Major advantages of mix bean were good taste, high yield, easy to cultivate, cook and market, low infestation of diseases and insects, drought tolerance, nutritious, etc. Farmers are reported bean mix as an easy practice and no specific problems have been reported. All respondents said that mix bean have good taste and no risk of crop failure. Price of mix bean is same as of other bean, however, Kaalo Maale Simee get premium price and therefore, farmers grow this landrace separately. Mix with higher proportion of Kaalo Maale Simee fetch higher price and become tastier. Mix bean in Pokhara, Nepalgunj and Kathmandu cost higher almost double than other normal mono variety bean. Through this technology, at least 9 native bean landraces are being conserved on-farm and because of widely adopted technology, there is no risk of losing bean landraces from Humla and Jumla. This practice though very common and old, has not been supported by any development organizations. It needs further research and support be improved and supported for making farmers more benefited.

Keywords: Bean mixture, conservation, disease, good taste, risk

INTRODUCTION

Bean is one of the important pulse crops in the mountains of Nepal. It has good economic value with high export potential in Western Nepal especially in Jumla and Humla (Bhujel 2014). Bean can be grown from lowland of Tarai to up to 3200 masl and cultivated for vegetables (green pods) and grain (daal) purpose. The bean for grain (making *daal*) purpose is reported to be cultivated up to 3121 masl in Yalbang, Humla (Shrestha et al 2015). Beans are usually consumed as *daal* (thick soup from spliited grain), cooked whole grain and for porridge. The historical use and importance of beans are the major source of food and nutrition for the high mountain communities in Nepal, including those of Mustang, Manang, Rasuwa, Solukhumbu, Karnali and far western high mountains. *Daal*, *bhaat* (cooked grain) and *tarkaari* (vegetables) are the typical Nepali meal consumes two times daily by almost all households in Nepal. Bean *daal* and other recipes made from bean has made this food healthy diet and nutritious. So far, 3 varieties of beans have been registered in Nepal and only one is suitable for high mountain cultivation (Joshi et al 2017). This improved bean variety officially recommended is not easily available and suitable for cultivation for grain (for *daal*) in the mountain areas, therefore, farmers rely on their own germplasm diversity.

The traditional practice of bean cultivation is quite unique and also contributes in providing solutions to combat biotic and abiotic stresses. Jumli beans have good demand (because of organic, good taste and high-land product), but till date, no systematic market channel for these beans exists. Collectors collect and send the beans directly to Kathmandu and other markets. The cultivation practices of landraces mixture have been passed down since generations and farmer communities have been practicing this. A wide range of variation in seed coat color, seed shape, plant type, leaf size and shape, pod color, pod shape, nodulation, root length, maturity, seed yields have been reported in Jumli bean collections (Neupane et al 2007). Most of the local landraces were a mixture of different types of bean, varying in seed size, shape, and color (Bhujel et al 2014). The mixtures of landraces with different size and seed coat patterns are harvested and sold in the market as mixed beans (Shrestha et al 2011). Local bean mixture has become sources of gene pool for developing modern pure line variety (Neupane et al 2007, Bhujel et al 2014). In addition, Jumli bean has been considered as geographical indication based on survey and nutrition analysis (Joshi et al 2020b). Significant differences in the landraces both within and among locations have been reported on high altitude bean landraces (Aryal et al 2020).

Growing varietal mixtures is a relatively common practice for beans in Humla and Jumla when compared to other mandate crops. The project baseline survey shows that 88% of households in Chippra and 98% of households in Hanku grow beans (Palikhey et al 2016, Parajuli et al 2016). Among the growers, 29% in Chippra and 40% in Hanku grow beans in mixtures (Chippra 63/72 bean growers and 18/63 growing as mixtures; Hanku 82/83 bean growers and 33/82 growing as mixtures). This study tried to understand why this cultivation practice is adopted for beans and why it has been used less frequently for other crops. This information will help relevant stakeholders working in Karnali that will guide on where interventions are needed in the value chain and management of native crop landraces. Major research questions of this study were:

- Why do farmers grow cultivar mixtures of bean in mountain regions?
- Do all social groups / category of farmers grow bean mixtures?
- What are the practices and production systems in the cultivation of bean mixtures?
- Do traders have incentives to sell mixed bean in the markets?
- Do mixed bean grains fetch equal or higher prices than single variety bean grains?
- Do all consumers prefer *daal* from mixed beans? If yes why do they prefer mixed bean grains?
- What are the comparative advantages of bean mixture with sole bean production?

METHODOLOGY

Two sites (villages) in each of two districts (Jumla and Humla) were selected where cultivation of bean mixtures is predominant, identified through key informant surveys / or expert consultations (eg DADOs, traders of mixed beans, etc). Two villages each from Jumla and Humla districts such asSarkideu and Chhipra in Humla and Hanku and Deopal Gaun in Jumla were selected for the study that represented and captures diversity of production systems, domains and dominance of bean mixture. Because survey of only project sites (eg Hanku in Jumla or Chhipra in Humla) may not capture the realistic information. Detail steps followed in this study are depicted in **Figure** 1. Survey were divided into two stages, first one was focus group discussion (FGD) supplemented by key informant survey (KIS) and second one was household (HH) survey. In this paper findings of only first stage of survey are reported.

This first stage survey constitutes one male group and one female group FGD in each selected village in each district. Both mixtures and mono cultivar growers were involved in focus group discussion. There were 6-11 participants in each FGD (**Figure** 2). Participants were identified after discussion with relevant key informants. Main target of FGD (through gender group discussion, GGD) was to identify the universe of possible reasons/explanations (a list of possible explanations) farmers have for practicing the varietal mixture in beans.

Key informant surveys were conducted by selected most knowledgeable stakeholders covering farmers, consumers, traders and local R & D officials of the locality (district). A total of 3 growers, 3 consumers, 2 R & D officers and 1 trader in Humla, and 5 growers, 5 consumers, 5 R & D officers and 3 traders in Jumla were interviewed purposively using specific semi-structured questionnaires. Questionnaires were different for each of stakeholder types such as farmers, traders, consumers and R&D officials. Sample size and number of questions asked or discussed for FGD and KIS are defined in **Figure** 2. Priority was given to KIS who were knowledgeable, experiences on production, marketing and consumption (eg food use) knowledge of bean mixtures including the mono cultivar system.

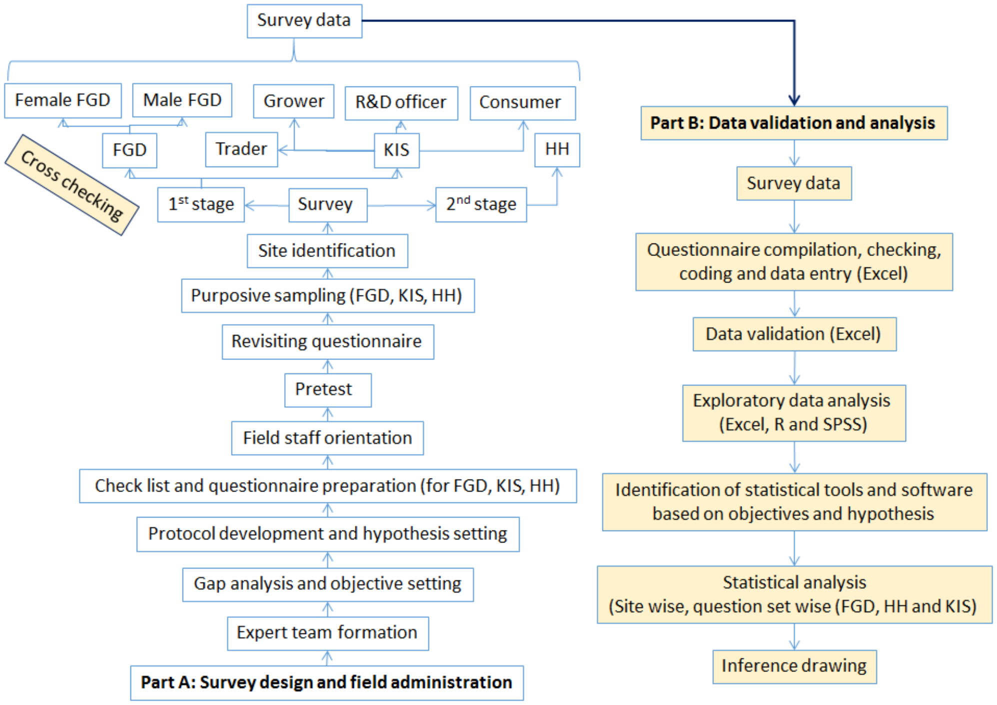

Figure 1. Steps of bean survey in Jumla and Humla, and data analysis used in this study.
HH, household; FGD, focus group discussion; KIS, key informant survey.

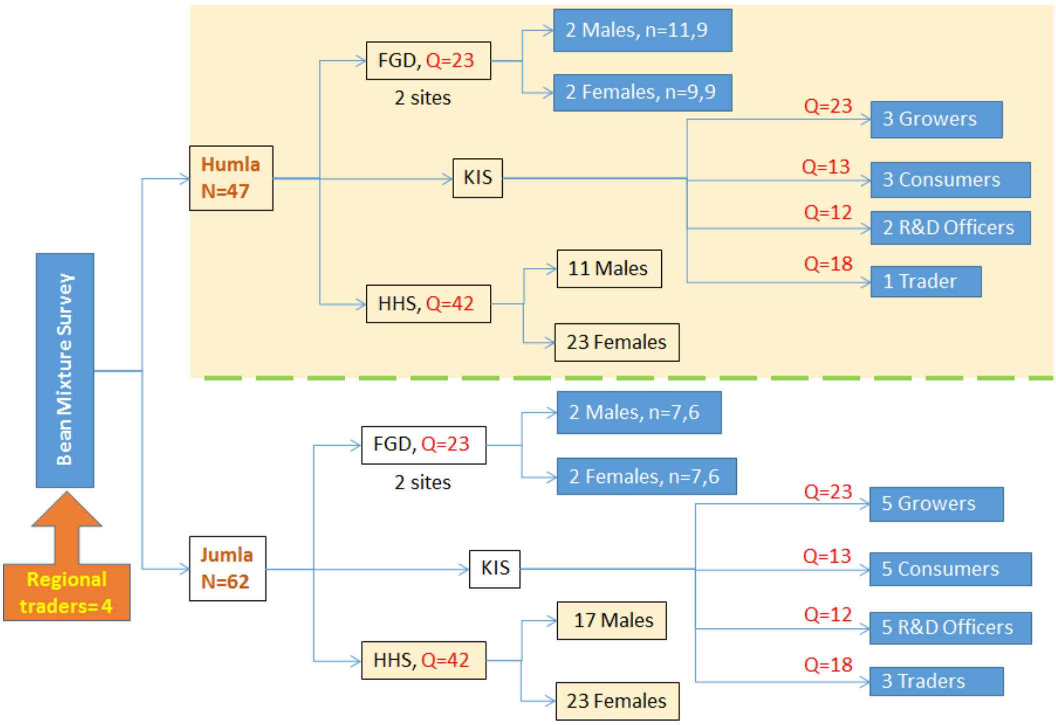

Figure 2. Survey sites along with survey methods and sample sizes.
Q, total number of questions; N, n, number of samples; HHs, household survey; KIS, key informant survey; FGD, focus group discussion.

Questionnaires for FGD and KIS were prepared based on the semis-structured checklists. Checklists for questionnaire was designed targeting to farmers in Karnali mountains growing beans in a mixture because it is how they produce and consume it.

Field staff were trained before administration of the questionnaire in the field. Staff had involved directly for site selection, participants selection and filling the questionnaire. After collection of data, it was further validated by project team sitting together with the field staff and checking each of the response of the question. Responses of the questions were coded in each category by production, marketing, consumption and overall constraints and issues by locations, gender and stakeholder types (producer, trader, consumer, R & D official). They were tabulated, summarized and analyzed.

FINDINGS AND DISCUSSION

Bean production practices

The bean is an important crop commonly cultivated in a range of 1600-3121 masl in Humla and Jumla districts. Both bush and trailing type of beans are grown and consumed by the farmers. They are grown mainly for grain purpose (*daal* and porridge). Some farmers also use it as green pod for vegetables. Beans are either sole cropped or mixed cropped with maize, proso millet, foxtail millet and finger millet. They are normally planted in April-May and harvested in September-October. Farmers do adopt both mixture and sole landrace cropping in all sites of Jumla and Humla districts. Landrace with high market price and long vein (pole type) and large canopy are grown single. Bean mixture is very old practices in both districts and do not know the exact date of start. Knowledge has been transferred from generation to generation as well as from neighbors. Same kinds of mixture components as well as practices have followed in all areas of Jumla and Humla. There are many numbers of bean landraces in Unapani and Gusa of Humla. Farmers said there are more than 20 landraces in mixture in some areas. All agreed that beans also help improve soil and keep soil loose, however, other benefits of mixture on soil are not fully known. In all sites, farmers sell mixture beans nearby local market as well as directly to staff, police, trader, neighbors and visitors.

Perception of male and female groups on bean mixture cultivation

The response of FGD from both male and female groups are presented in **Table** 1. In Jumla, there is high level of similarity between male and female groups in their answer for each question. Female group have added few more reasons of mixing bean landraces. They said, mixture can do better even during drought period. The main reasons of mixing bean landraces were high yield, high market price, good taste and no risk of cultivation.

In Humla too, male and female groups have same answers for all questions in both sites (Sarkideu, Unapani and Chhipra, Nalla, Humla), except in some aspects. Male group added some extra reasons of cultivation of bean mixture. They said that mixture has complementary effects, that is, if one pure line type of bean is disease susceptible, the other pure line is disease resistant, Similarly, if one pure line is high yielding with low taste, the other type is tastier despite their low yielding ability. Hence, farmers have practice of mixing different types to get complementarity benefits. For example, Kaalo Maale has good taste, some other landrace yields higher but not good taste, Seto Daale Chuke makes *daal* thick and gravy. Male group are also more familiar with price, eg Kaalo Maale can be sold at higher price than mixture. They suggest that proportion of Kaalo Maale should be increased to get higher price. Female group were found more concerned on cooking time, saving time, laborious and mixture in other crops. Main reasons of mixing bean landraces were good taste, easiness of cultivation and no risk of complete crop failure.

Mixtures of higher number of landraces are found in Humla than in Jumla (**Table** 1). Mixture practice has not been adopted in other crops in Jumla, but it is practiced in amaranth and wheat in Humla. In both districts, mixing bean landraces with Kaalo Simee (small size) was found profitable mainly Kaalo Simee makes food tasty. Farmers in both districts consider diverse set of landraces for mixing and they have good experiences of minimizing the risk of crop failure from mixture system. In Jumla, participants said that price for both sole and mix bean are same whereas, in Humla, mix bean generally get premium price.

Table 1. Summary responses of the focus group in Jumla and Humla on bean mixture related questions

SN	Mixture question	FG responses	
		Hanku and Deopal Gaun, Jumla	Sakideu and Chhipra, Humla
	Group and participants (n) site 1 + site 2	Female (6+7) and Male group (6+7)	• Male (11+9) and Female group (9+9)
1.	Reasons and advantages of mixture cultivation 7	• Easy to sell • High price • High yield • Less storage pests • Low insect and disease problems • Low risk of crop failure • Old practice • Produce well even in drought period • Some are good for yield and some are less susceptible to insects • Some landrace work well in rainy time and some drought period • Tasty • Lake of seed for sole crop • Difficult in seed separation • Cultivation practice is easy • Harvest multiple variety from single land at a same time • Varietal mixture gives higher production then sole crop	• All practice mixture and it is old practice • Compensate yield even in bad year or in poor land • Complementary effects in mixture • Cook well • Easy to cultivate • Grow and mature together and easy to harvest and store • High yield and higher from fertile land • Low diseases • No chance of diseases in all plants • No risk of whole crop failure • No storage problem • Produce well even in poor soil • Same price for mix and sole • Seed not enough for sole cropping • Tasty *daal* • Easy cultivation practice • Lack of seed for single variety • Harvest multiple variety from single land at a same time.
2.	Cultivation of single landrace and its reason	• Rato Simee, Kalo Simee and Seto Simee • Sole crop in upland areas • Grow single variety in marginal land (*Pakho Bari*, upland)	• Kaalo (Ghar or Jhal) Simee as sole • Large canopy makes shade to others • High price and demand
3.	Mixture components	• 3-5 • Raato Simee, Kaalo Simee, Seto Simee and Chhirkemirke (mosaic) Simee	• All Simee except Kaalo (up to 9) • Chuke (Radale, Maluwa Maale), Raato Maale (Naini Taale), Kaalo Maale (Sano And Thulo) Raato Baatulle, Ghiu Simee, Dudhe Simee, Pahenle Simee, Saano Kaalo Maale, Jumla Kaalo, Deshi Simee, Jumli Kaalo Simee
4.	Mixture in other crops	• None	• None • Sometime in amaranth and wheat (Maluwa Pawai and Lomdya mix and they mature at same time)
5.	Reason of not practicing mixture in other crops	• Mature at different time • Not tasty	• Do not mature at same time • Difficult to harvest • Difficult to cook • Different cooking time
6.	Characters of landraces for mixture	• Raato Simee not good and mix with Kaalo Simee • Less valued landraces mix with high valued ones	• All mix except Ghar Simee • 7-10 landraces with same maturity period
7.	Seed storage and harvesting methods for mixture	• Mix all landraces that mature at same time • Sun-dried and store in tin box	• Harvest together, keep together • Sun-dried before threshing, and storing • Store in wooden or plastic pot
8.	Selection for mixing seeds	• No • Low amount of Raato Simee in mixture	• No selection • Selection sometimes to early maturity type
9.	Bean mixture in intercropping	• With maize	• Separately as well as mix with maize, finger millet, potato or proso millet
10.	Lesson learnt from mix and sole	• Low problem of insects and diseases in mixture • Easy marketing for mixture products	• In mixture, some years some components do better and in others some components do better

SN	Mixture question	FG responses	
		Hanku and Deopal Gaun, Jumla	Sakideu and Chhipra, Humla
	cropping of bean landraces		• Sole cropping are risky of complete failure, sometime damage completely by insects and diseases but not in mixture • Less laborious • Save time • Good even in drought time
11.	Disadvantages of mixture cultivation	• Difficult to harvest if do not mature at same time	• Some mature late • Less price compared to Kaalo Maale • Difficult to harvest if do not mature at same time
12.	Suggestions for mixture cultivation	• Mix landraces at certain proportion • Need landraces having same maturity period • Mix low amount of Raato Simee for good mixture harvest and very tasty • Make mixture of early maturing type and late maturing type	• Need to separate early and late maturing landraces • Increase proportion of Kaalo Maale in mixture to get higher price

Farmers have reported number of different landraces that mix together in Humla (Table 2). Seed morphology is the major descriptors used by farmers for treating genotype as a separate landrace. Landrace with seed characters are given in Table 2. Farmer's names to landraces are based on seed color and shape.

Table 2. Landraces used in mixture and their seed characters (from Humla)

SN	Landrace	Seed characters
1.	Chuke (Radale, Maluwa Maale)	Long like egg shape; black or red spot or lines on white background, mosaic seed surface; major seed surface is white
2.	Dudhe Simee	White, small and shiny
3.	Ghiu Simee	Ghiu color, round (golo)
4.	Jumla Kaalo Simee	Similar ot Ghar Simee, black and small
5.	Kaalo Maale (Nain Tale)	Similar to Raato Maale, except white spot or lines in black or blue color mosaic seed surface
6.	Pahenlo Simee, Desi Simee	Yellow, long and thin
7.	Raato Baatulo	Completely red, shiny, small and round (Baatulo) shape
8.	Raato Maale (Naini Taale)	Thinner than Chuke, dark red spot or lines, mosaic seed surface
9.	Saano Kaalo (Naini Taale Saano)	Small, black

Perceptions of individual growers on bean mixture

Responses of the survey from individual farmers / growers in both districts were similar for the bean mixture as that gathered from FGD for male and female groups. Some growers said that, they mix beans together and do intercropping because of limited land. Mixture can also easily be sold in the market. Mixing low and good quality beans together makes better in total. Mixing everything is very easy technique (for cultivation, harvesting, storage, cook, etc) and if someone tries to separate it is very tedious / labor intensive. There is high demand price of Ghar Simee bean (Kaalo Maale Simee), therefore, this Simee is grown separately. In mixture, some landrace may mature early which can be harvested early, but sometimes they burst and lost the seeds if kept longer time after maturity. They prefer mixing bean landraces because of low diseases problems, high yield, tasty and high market demand. Mostly 4-7 types of seeds were found to be mixed together.

Perceptions of R&D officers

In Humla, only one organization (officer) working on the agriculture sector was familiar with bean mixture. This organization has program related to awareness raising, collection and distribution of diversity kit, establishment of diversity block and training, and started working since 2011. Other organizations did not have any program on bean mixture, though they know the advantages of bean mixture. Major bean mixture areas are Kharpelgaun, Laali, Gopka, Raya, Gumba, Karanga, Ripa and Unapani villages in Humla. Major reasons of mixing beans were: if one landrace fails, other produce well, more benefit, better nutrient management, traditional system, small landholdings, compatibility for intercrop with maize. Mixture system does not exist in other crops mainly because of not availability of varieties with same maturity period. Major problems in mixture are difficult to thresh and lack of irrigation. They suggested for supporting on processing and marketing of mixture, publication on importance of mixture and mainstreaming bean mixture program. It is noticed that organizations are mainly focusing on other than native genetic resources and technologies.

In Jumla, among the five interviewed officers, all are not familiar and have not any programs and support on bean mixture except one research organization. All officers reported that, bean mixture has advantages of high yield, easiness to cultivate, high market value and demand. Researches on mixture in bean, buckwheat, rice and barley have been started in Jumla since 2016. They suggested for the inclusion of high yielding varieties in mixture and technology development. Mixture is very old and common practice in both districts however, R&D organizations have not given due priority for improving this technique.

Perceptions of traders

All traders in both districts have similar kinds of responses. Selling mix bean is very old tradition and both mixture and sole bean are being sold in the markets in both districts. Main consumers are officials, traders and local people. Demand of sole bean of Kaalo Male Simee is higher as compared to mix bean in Humla but mix bean is valued more in Jumla. Demand of mixture with Kaalo and Seto Simee is higher in Jumla. Mix beans are tasty and last longer (slow digestion) in the stomach (*faaro,* long lasting) as rich in protein and normally are insect and disease free. Generally, there are 3 to 10 types of landraces in mixture bean that are kept for sale. In Humla, only one type of mixture bean is sold, however, there are 2 to 4 types of different mixture bean in Jumla. Price for mixture bean in Jumla is same as sole bean, however, price of Kaalo Maale Simee is higher than any other beans. Mixed bean is cheaper but its benefit is higher compared to others. Consumers buy mixed bean for consumptions but few farmers buy such bean for planting purposes. Mixed beans are collected from nearby village as well as from some farmers' groups. Some traders said, they prefer to sell sole bean (mainly Kaalo Maale Simee) as there is high demand and profit. In Jumla, traders also prefer to sell mixed bean with Kaalo and Raato Simee. Traders suggested that proportion of Kaalo Maale Simee should be higher. Quality of mixed bean also depends on farmers method of production as, some farmers have good quality mixed beans.

Perceptions of consumers

Consumers in Humla eat mixed bean and this is very old practice. Main reasons are easily available, tasty, last long after consumed (*faaro*). Preference for consummation of mixed is also not enough availability of only Kaalo Maale Simee type. There are generally 5-7 different types in a mixture, some are Kaalo Maale, Raato Maale, Dalle Seto, Ghiu Simee, Dudhe Simee, Jumli Kaalo, Deshi Simee and Seto Simee. Respondents including all family members preferred mixed of Kaalo and Raato Simee. Cooking time is same as other beans. Maale Simee taste better than other types. Price of mixed bean is same as others. Food items prepared from mixed beans are *Daal, Gedaagudi, Simee Kol, Simee Khutti, Khichadi,* etc. Separating different bean types is very difficult, therefore, they use mixed bean as it is. In Jumla, all consumers have similar responses as in Humla except few responses. They prefer mixed of Kaalo, and Raato but two consumers preferred mixed bean with Chhirbire Simee (spotted bean) and Pahenle Simee (yellow bean). Mixed beans are cheaper and cook faster, easy to cook and nutritious. They are using mixed bean because there are no other alternatives of having sole type.

Determinant factors for mixing bean landraces

Mixed bean is common practice both in Jumla and Humla and its advantages are tasty, easy for cultivation, no difficulty to harvest even mature at different period, low insects and diseases, possible to harvest many landraces within a short period of time, etc. The determinant factors for using mix bean are small and marginal land; limited crops growing options; risk of crop failure from insects, diseases and drought; easy cultivation, harvesting and storing; better taste; nutritious and high value given for beans by consumers and traders.

The common practice was mixing 3-6 different types of beans (mainly black, yellow, white, mosaic, brown and red) whereas maximum number of mixing bean landraces were nine. Selection of components in bean mixture is predominantly based on color. Black type is most preferred due to its better taste and red type is least preferred due to inferior taste. Mottled type which is locally called *Maale* is also included in some of the mixtures. Seed size is very rarely considered in mixture, however, some farmers considered seed shape eg *thulo* (larger shape), *baatulo* (round), *chepto* (flat). The proportion of seeds of mixing landraces is not standardized but generally; black being good in taste is included in larger quantity and red in the least quantity. The most important character considered for selection in the mixture is time of maturity and farmers mix landraces that mature at same time. This synchronized maturity in the mixture ease farmers to harvest.

Farmers believed that mixture in bean is practiced primarily to combat pest and disease problem (Joshi et al 2020c). Some lines in bean mixture were found to be relatively more resistant to pest and diseases (Aryal et al 2020, Prasad et al 2016). The proportion of resistant varieties in a mixture and the arrangement type significantly decreased bean fly damage compared to pure stands (Sekandi et al 2016). In addition, farmers also perceived good harvest and better taste from mixture. Mixed beans usually fetch premium price and some perceive it to be easy for cultivation. Black type and mixed type possess higher demand in the market. Beans with darker colored seed possess the highest phytochemical and antioxidant, which may be reduced during cooking if not properly cooked (Subba et al 2016). Jumli Simee is relatively nutritious due to their richness in polyphenols (Joshi et al 2020b). Protein content of Sthaaniya Kaalo Simee was the highest and Sthaaniya Raato Simee possesses the highest amount of polyphenol, and antioxidant (Joshi et al 2020b).

Mixture is not common in other crops as in the common bean, however, few farmers grow mixture of amaranth and wheat landraces. Cultivars mixture should also be extended to other crops as a part of conservation plant breeding and reducing risk of cultivation in marginal environments. Major factors for mixing landraces are their maturity. They should mature at the same time and should not have shading effects to each other. Jhal Simee (Ghar Simee, Kaalo Maale Simee) is grown single mostly intercropped with maize, proso millet, foxtail millet and finger millet. Both sole and mixture cropping is prevalent and sole crop are usually cultivated in the upland (paakho bari). Mixture is now decreasing because of high price of Kaalo Maale Simee grown as a sole landrace cropping. This bean is grown in upland areas. Some farmers if grow bean separately, they mix together after harvest. In the context of 40% loss of agrobiodiversity in Nepal (Joshi et al 2020a), cultivar mixture is the simple on-farm conservation method (Joshi and Upadhaya 2019) and have been effective for getting multiple benefits (Joshi et al 2018, Joshi et al 2020d).

CONCLUSIONS

Farmers in Jmula and Humla found to grow beans in a mixture to manage risks associated with disease and pest damage including climate uncertainty and poor soil conditions. They grow beans in a mixture also because it is a traditional practice they have followed over generation. Landraces with similar maturity period are mixed together that makes easy to harvest. Bean mixture assures harvest even in bad conditions eg drought period, diseases and insects infestation. This technology can be considered simple both for conservation of crop diversity and sustainable production in mountain agriculture. Farmers consider maturity period of varieties to be mixed as determinant factors and considering maturity period, similar approach can be extended to other crops as well. Research and development programs need to include for strengthening the traditionally rooted technology and native genetic crop landraces. Further in-depth investigation through sample structured household surveys is suggested to validate present findings and identify more other determinants of mixture cultivation in the mountains of Nepal.

ACKNOWLEDGEMENTS

Support from farmers, ARS, Jumla are highly appreciated. Special thanks go to project staff (Kabita Jaisi, Dalaki Sherpa, Paras Mahat in Jumla; Hira Devi Hamal, Sundar Rawat in Humla; Surendra Shrestha and Safal Khatiwada in Kathmandu) for facilitating the experiment.

REFERENCES

Aryal K, S Poudel, P Chaudhary, RP Chaudhary, KH Ghimire, DS Shrestha and BK Joshi. 2020. Agro-morphological diversity of high altitude bean landraces in Kailash Sacred Landscape in Nepal. Journal of Nepal Agricultural Research Council **6**:1-13. **DOI**: https://doi.org/10.3126/jnarc.v6i0.28109

Bhujel RB, CB Rana, PM Mahat, S Subedi and LL Shrestha. 2014. Evaluation of bean (*Phaseolous vulgaris*) as an Important pulse and cash crop in Jumla and similar high hill region of Nepal. **In**: Proc. 27th national Summer Crops Workshop. National Maize Research Program, NARC, Rampur, Chitwan; **pp**. 22-27.

Joshi BK and D Upadhya. 2019. On-farm conservation approaches for agricultural biodiversity in Nepal. Journal of Agriculture and Natural Resources **2**:14-35. **DOI**: https://doi.org/10.3126/janr.v2i1.26012

Joshi BK, D Gauchan, BR Sthapit, R Gurung, SB Gurung and S Gautam. 2018. Cultivars mixture and its advantages. Briefing Paper 9 Year 2074. LIBIRD, NAGRC, DoA and Bioversity International, Nepal (In Nepali language).

Joshi BK, MR Bhatta, KH Ghimire, M Khanal, SB Gurung, R Dhakal and BR Sthapit. 2017. Released and Promising Crop Varieties of Mountain Agriculture in Nepal (1959-2016). LI-BIRD, NARC, and Bioversity International, Pokhara, Nepal. https://www.bioversityinternational.org/fileadmin/user_upload/Released_and_promising_crop_varieties.pdf

Joshi BK, N Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020a. 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 BK, P Ojha, D Gauchan, KH Ghimire, B Bhandari and HB KC. 2020b. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D Jarvis, eds). Proceedings of GEF UNEP Local Crop Project, Kathmandu, Nepal; NARC LI-BIRD and Bioversity International. In this book.

Joshi BK, SB Gurung, SP Vista, PB Paneru, R Gurung and S Pant. 2020c. Cultivar mixture. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**. 65-70.

Joshi BK, SP Vista, SB Gurung, KHi Ghimire, R Gurung, S Pant, S Gautam and PB Paneru. 2020d. Cultivar mixture for minimizing risk in agriculture farming and conserving agrobiodiversity. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D Jarvis, eds). Proceedings of GEF UNEP Local Crop Project, Kathmandu, Nepal; NARC LI-BIRD and Bioversity International. In this book.

Neupane RK, R Shrestha, ML Vaidya, EM Bhattarai and R Darai. 2007. Agromorphological diversity in common bean (*Phaseolus vulgaris* L.) landraces of Jumla, Nepal. **In**: Proc. Fourth International Food Legumes Research Conference (IFLRC-IV) (MC Kharkwal, ed). 18-22 October 2005, New Delhi, India; **pp**. 1-11.

Palikhey E, SR Sthapit, S Gautam, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report III. Hanku, Jumla. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal. https://cgspace.cgiar.org/handle/10568/92460

Parajuli A, A Subedi, AR Adhikari, SR Sthapit, BK Joshi, D Gauchan, B Bhandari and BR Sthapit. 2016. Baseline Survey Report: IV. Chhipra, Humla. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal. https://cgspace.cgiar.org/handle/10568/92446

Prasad RC, MN Paudel, NH Ghimire and BK Joshi. 2016. Cultivars mixtures in bean reduced disease infestation and increased grain yield under mountain environment of Nepal. Agronomy Journal of Nepal **4**:126-133. https://www.nepjol.info/index.php/AJN/article/view/15535

Sekandi W, JW Mulumba, P Colangelo, R Nankya, C Fadda, J Karungi, M Otim, P De Santis and DI Jarvis. 2016. The use of common bean (*Phaseolus vulgaris*) traditional varieties and their mixtures with commercial varieties to manage bean fly (*Ophiomyia* spp.) infestations in Uganda. J. Pest Sci. **89**:45-57. **DOI**: https://doi.org/10.1007/s10340-015-0678-7.

Shrestha R, RN Neupane and NP Adhikari. 2011. Status and future prospects of pulses in Nepal. Paper presented at Regional Workshop on Pulse Production. 24-25 Oct 2011, Kathmandu. Nepal Agricultural Research Council (NARC), Kathmandu, Nepal.

Shrestha SD, B Sthapit and D Gauchan. 2015. Bean Cultivation and Seed Production Technology. Information Flyer 7. UNEP GEF Project. NARC, LI-BIRD and Bioversity International, Kathmandu, Nepal.

Subba S, PK Poudel and GP Kharel. 2016. Study on phytochemicals present in Jumli Simee and effect of cooking on them. Golden Gate Journal of Science & Technology, **pp**.1-8.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project; Nepal, NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Factors Influencing Cultivation and Promotion of Traditional Crops in the Mountains: A Case of Jumla District, Nepal

Dinesh Babu Thapa Magar, Devendra Gauchan and Bal Krishna Joshi

ABSTRACT

A study was conducted to assess the status of traditional mountain crops and factors influencing their cultivation and promotion in Jumla district of Nepal. Primary data were collected through focus group discussions with the farmers in Hanku and Talium villages; interactions with governmental, non-governmental organizations and private sectors; and interviews with local key informants in 2016. The study revealed almost stable production of major cereals such as rice, maize, and finger millet, declining production of wheat and increasing production of barley in the district. Similarly, the available secondary data showed limited cultivation of traditional minor crops such as prosomillet, buckwheat, foxtail millet and naked barley in a very small area of land compared to major cereals but with stable production trend. However, the farmers and other local stakeholders perceived a rapid decline in farming of these traditional minor crops in the district. As they reported, the major reasons behind such a decline included physical factors (improved road/market and food access), socio-cultural factors (changing food habits and social taboos), institutional/policy factors (discriminatory support services towards minor crops), economic factors (lack of market demand and profits of minor crops), technical factors (lack of improved technologies and package of practices for the minor crops) and environmental/bio-physical factors (damage from the pests and diseases/climatic stresses). The continuous decline of cultivation of these traditional and minor crops might result in irreversible loss of the local food system and crop diversity, causing serious risk to the people and ecosystem of the mountainous region. It is therefore crucial to mainstream traditional mountain crops for ensuring improved biodiversity as well as sustainable food, nutrition and income to the communities in the mountain regions of Nepal.

Keywords: Access to market, crop diversity, influencing factors, subsidy, traditional mountain crops

INTRODUCTION

Agricultural biodiversity comprises all components of biological diversity related to the production of goods in agricultural systems - the variety and variability of plants, animals and microorganisms at genetic, species and ecosystem levels that are necessary to sustain key functions, structures and processes in the agro-ecosystem (FAO 1999, Jarvis et al 2007). Crop genetic diversity refers to the diversities within and among crops and varieties, their wild relatives and wild edible plant species used by communities for food and agriculture (FAO 2014). The genetic diversities present in the crops particularly in traditional crops/varieties are the most economically valuable part of global biodiversity and are very crucial for future world crop production (Wood and Lenne 1997). Traditional crops, including neglected and underutilized ones (Joshi et al 2019), may be low-yielding but they are highly adaptable to marginal and variable climatic production environments, suited to diverse socio-cultural and economic conditions, have capacity to withstand climatic stresses and disease epidemics (Jarvis et al 2016, Jarvis et al 2011), and are usually grown in marginal or degraded land with low-inputs. Additionally, they play a vital role in food and nutrition security as well as crop diversification, environmental improvement (Padulosi et al 2011, Frison et al 2006) and ultimately offer opportunities for strengthening the adaptation, mitigation and resilience of both the natural and socioeconomic systems to climate change (Padulosi et al 2011). Food production and security depend on the rational use and conservation of agricultural biodiversity and genetic resources (Alcázar 2006). However, global food security has become increasingly dependent on a limited number of varieties of a few major crops and higher reliance on such a narrow food base makes food, nutrition and income security of the farmers extremely vulnerable in the changing environment (Sthapit and Padulosi 2011, Joshi et al 2016, Joshi et al 2017b). The commercial benefits and yield superiority offered by mono-cropping and many improved hybrid crops while lack of investment and adequate attention by researcher and policy makers including low competitiveness and infrastructures for local, traditional and minor crop or neglected and underutilized crop species (NUCs) and varieties in many areas has led to the loss of crop diversity along with a wealth of traditional knowledge about their cultivation and uses (Padulosi et al 2013, Joshi et al 2020a).

Nepal is a small mountainous country, but it is rich in biodiversity due to its varied topography, micro-climates and socio-cultural settings (Upadhyay and Joshi 2003). More than 550 crop species are identified as having food value, and around half of those species are cultivated within the altitude range of 60 m to 4700 m above sea level (MoFSC 2002, Joshi et al 2017a). Nepal is broadly divided into three geographical regions viz. mountain, hill and Tarai (plain), and majority of the land in the country falls in the hills and the mountain regions with a share of 42% and 35%, respectively, while Tarai, which is also called as a grain basket of the country, accounts for only 23% of the total land (MoAD 2015). Due to varying altitudes, slopes, aspects and soil types over short distances, mountain region exhibits different micro-ecosystems (different crops, varieties, cropping patterns etc) (ICIMOD 1987). Although mountain farming systems consist of considerable diversity in ecosystem and genetic resources, they are generally extremely fragile due to steep slopes, erodible soils, intense rainfall, intensive cultivation and uncertain markets.

Traditional farming system practiced by the farmers for many years in the mountain region has developed the region as a unique diversity center of globally important crop species, including cold tolerant rice, naked barley, barley, buckwheat, amaranth, bean and minor millets such as proso millet, foxtail millet and finger millet. These crops are hardy, cultivated in marginal lands with minimal external inputs, and are widely adapted and tolerant to cold and drought stress. Furthermore, mountain crops are rich in micro-nutrients and important for food and nutrition security of the communities in the mountain regions of Nepal (Bajracharya et al 2013, Gauchan and Khanal 2013, Joshi et al 2020b). However, like in many other countries, various studies in Nepal have also revealed a loss of biodiversity particularly of the traditional crops due to socio-demographic changes such as population growth and rural out-migration, changes in cropping patterns and land use practices, lack of markets, technological advancements and changes in food habits, poor focus and supports to the traditional crops while promotion of modern crop varieties from the public sector, lack of knowledge about the cultivation, use and nutritional values of the traditional crops, and rapidly changing social psychology that conceive farming and consumption of traditional crops as poor households obligations (Adhikari et al 2017, Gauchan and Khanal 2013, Joshi et al 1998, Gauchan et al 2005, Uprety and Uprety 2001, Upadhyay and Joshi 2003, Joshi et al 2020a).

Jumla (2200-3050 masl) is a remote and mountainous district of Nepal which represents the high altitude agro-ecosystems of the country with rice cultivation at the highest elevation (3050 masl) in the world (Joshi 2004, Joshi et al 2020a). Jumla harbors unique crop diversity with landraces adapted to local traditional farming systems, agro-ecological niches, socio-cultural settings and economic standards of the farmers (Baniya et al 2003, Paudyal et al 1998, Bajracharya et al 2010). However, information on status of and factors influencing the cultivation and promotion of that are traditionally grown in the district is very limited. Therefore, this study was conducted in Jumla district to assess the status of traditionally grown crops cultivated particularly of major cereal crops (rice, maize, wheat, barley and finger millet) and minor cereal crops (proso millet, foxtail millet, buckwheat, naked barely), and vegetable and fruit crops (bean and apple) that are increasingly becoming popular recently. The study also examines the factors influencing cultivation and promotion of traditional crops and suggests a plausible policy intervention for their conservation and promotion in mountainous environments.

METHODOLOGY

A case study was conducted in 2016 in Jumla district purposively because it represents the mountain environment with farming of many traditional mountain crops. Additionally, as this research was conducted as a part of the collaborative project, namely, “Local Crop Project” coordinated by Bioversity International, funded by UNEP-GEF, and in leadership of the National Agricultural Genetic Resources Centre (NAGRC)/ Nepal Agricultural Research Council (NARC), Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and the Department of Agriculture, two Village Development Committees (VDCs) namely Hanku and Talium VDCs of Jumla district where this project was implemented was purposively selected for this study. Two focus group discussions (FGDs), one in Hanku VDC and another in Talium VDC were conducted with participation of about 15 male and female farmers. Changing scenarios of agriculture, cropping patterns and practices, access to public supports including the factors influencing crop production in the VDCs were discussed and necessary information were collected. Efforts were made to have participation of farmers from each ward of the VDCs during FGDs.

Similarly, information on district level agricultural programs, subsidy and other input supports delivered to farmers, including crop diversity situations were obtained through the interaction with the District Agriculture Development

Office (DADO) team comprising primarily the staff having longer period of work experience in the district. Discussions on research activities and outputs associated with traditional crops were done with the Agriculture Research Station (ARS) of NARC at Vijayanagar, Jumla. Likewise, information on supply of subsidized food particularly rice was collected by interacting with Nepal Food Corporation (NFC) officials at Jumla and Kathmandu. Non-governmental organization (NGO) such as World Food Program (WFP), which was involved in implementing 'Food for Work" program and supporting people with food and cash in different villages of the district, was also consulted to understand the food support program. Another NGO, namely LI-BIRD, which was mainly involved in project implementation in the district was also interacted to collect the necessary information. Additionally, necessary information was also collected through the local key informants as well as review of published and un-published sources. Collected data were organized, analysed and presented in the graphical, tabular and textual forms.

RESULTS AND DISCUSSION

Status of cereal crops production in Nepal

The cereals crops grown in Nepal include paddy (rice), wheat, maize, finger millet, buckwheat, barley, naked barley, proso millet *(Chino)*, foxtail millet *(Kaguno)*. The official government statistics such as Statistical Information on Nepalese Agriculture published by the Ministry of Agricultural and Livestock Development has, however, no data and information for proso millet, foxtail millet and naked barley. The available cereal production data for the period of 2004/05 to 2015/16 show a higher cultivation of cereals such as paddy and wheat in the Tarai while maize, millet and buckwheat cultivation is higher in the hills and barley has been the major crop in the mountain region (**Figure** 1).

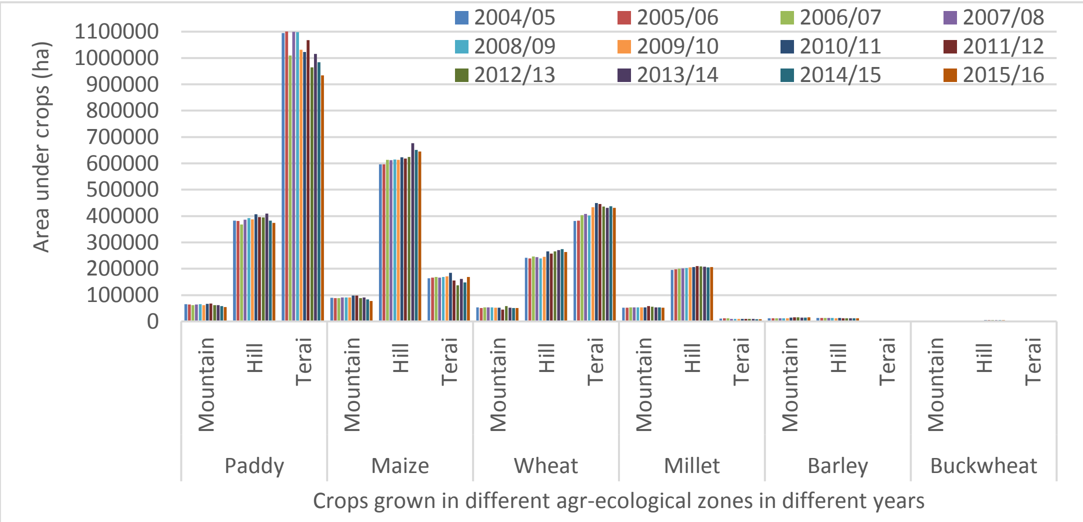

Figure 1. Area trend under cereal crops in different agro-ecological regions of Nepal.
Source: MoAD 2016.

Out of the total area grown under rice and wheat crops in Nepal, Tarai alone shares about 70% of the total rice area and 58% of the total wheat area. Similarly, hills are the major regions for maize, millet and buckwheat crops, which share about 71%, 76% and 46% of the total area under these crops, respectively. Whereas, nearly half of the total area under barely crop lies in the mountain region indicating it as a major cereal crop in the mountain region (**Figure** 2).

Overall, paddy stands in the first position while maize and wheat stand in second and third position in terms of the total area under cereal crops production in Nepal. The available data for the period of 2004/05 to 2015/16 shows the cultivation of rice, maize and wheat in about 44% (about 1.48 million ha), 26% (about 0.87 million ha) and 21% (about 0.72 million ha), respectively of the total land under cereal crops in Nepal.

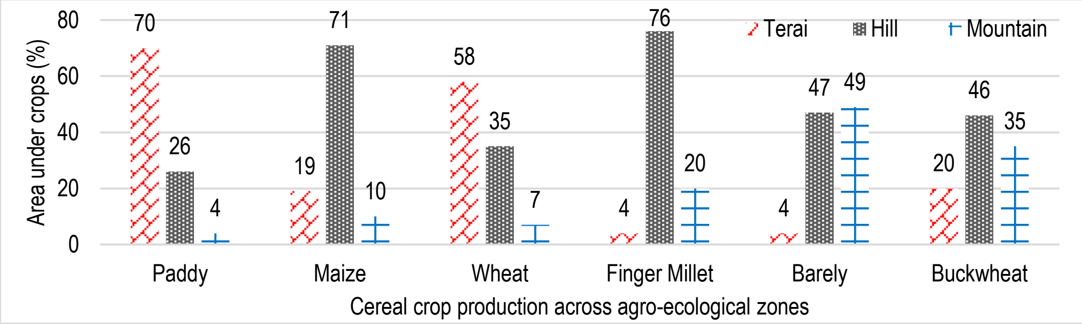

Figure 2. Average area of cereal crops cultivated in different agro-ecological zones.
Source: MoAD 2016.

The data show that the area under traditional mountain crop is very low. Only about 8% of the total land under cereal crops is covered by finger millet and less than 1% by barley and buckwheat crops in Nepal (**Figure** 3). Although barley and buckwheat are the major crops for the mountain regions, the area under cultivation of these crops are very negligible in the country compared to other major cereal crops.

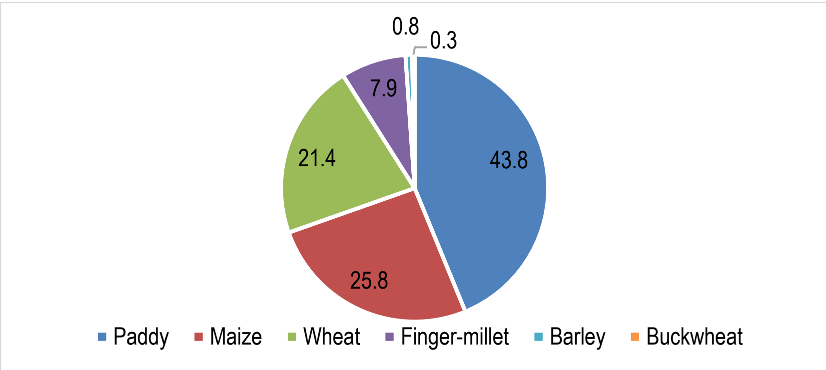

Figure 3. Average area under cereal crop production in Nepal (2004/05-2015/16).
Source: MoAD 2016.

Status of major traditional crop production in Jumla

Cereal crops such as rice, maize, barley, wheat, and finger millet are the major cereal crops in Jumla district. The area under maize is the highest (4500 hectares (ha), followed by barley and finger millet (about 4000 ha), paddy (3000 ha) and wheat (2500 ha) (**Figure** 4). The trend data of the cereal crop production for the past 12 years (2004/05-2015/16) shows almost stable trend in areas under maize, finger millet and rice crops while there are some fluctuations in the area under cultivation of barley and wheat crops. The barley area increased sharply in 2010/11 and declined in the following years but remained still higher than of 2009/10. Wheat area started declining since 2008/09 and had some fluctuations until 2012/13 and remained almost stable afterwards. There was not much difference in area under barley and wheat until 2006/07 but after that barley area increased sharply while wheat area started declining. Wheat and barley are grown in the same type of land during winter season, but unlike barley, wheat requires weeding operations demanding additional labor and cost for weed control. Additionally, wheat also matures later than barley which affects timely planting of rice crop. Furthermore, food preference and market opportunities are higher for barley than wheat, and these factors as reported by the farmers in FGDs have affected the cultivation of wheat in the district.

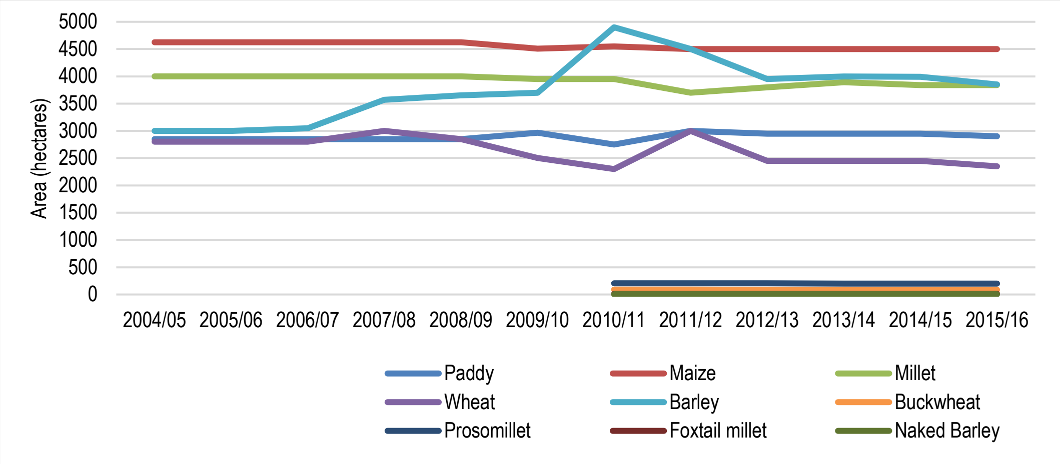

Figure 4. Trend of area under traditional cereal crops in Jumla district, Nepal.
Source: MoAD (2003/04 to 2014/15 for major cereals) and DADO Jumla (for minor cereals including 2015/16 data).

Minor cereal crops like proso millet, buckwheat, foxtail millet and naked barley are found to be grown only in about 200, 90, 13 and 5 hectares of land, respectively. During this study, the data for minor crops was available only for the past six years (2010/11 to 2015/16) and it shows stable trend for area under cultivation of these minor cereal crops. Available data also reveals a lower productivity of these minor crops including wheat and finger millet (1.0-1.2 Mt/ha) compared to other major cereal crops (rice, maize and barley) (1.5-2.5 Mt/ha). However, the farmers interacted in focus group discussions (FGDs) said and even DADO officials admitted that the production of these minor crops are declining at a rapid rate after having improved road connectivity and access to foods in the district. The district for many years was in isolation with limited access of its people to the external markets and related services. Now it is well connected to the external markets when the road track of the Karnali Highway (Surkhet-Jumla, 232 km) was opened in 2007 and later blacktopped (2010-2013). This development led not only the export of apple, bean, potato and vegetables from Jumla but also accelerated the import of food particularly rice and other goods in the district. Furthermore, it created more opportunities of non-farm employment and income generation to the people. With the increased income and access to the market and goods, traditional minor crop-based food habit of the people also started changing rapidly into rice-based food habits resulting into a decline of the minor cereal crop production in the district. Also, demand of apple and bean as cash crops increased and they started replacing low productive and less profitable crops such as proso millet, foxtail millet and naked barley. Importantly, local people producing and consuming minor crops for many generations were also increasingly seen as the people with lower status or prestige in the society. Such social taboos also quietly discouraged the farming and consumption of the minor crops in the district.

Status of major cash crops

Apple, bean and potato are the major cash crops in Jumla. Apple, bean and potato were grown in about 2900 ha, 2600 ha and 2200 ha of land, respectively in 2015/16 in the district (Figure 5). As depicted in the figure below, the area under these cash crops are increasing over the years which is mainly due to increased demand, market access as well as supports from the governmental and non-governmental organizations.

Varietal diversity and dominance of traditional mountain crops

The farmers in Jumla grow many traditional crops and mostly in a traditional way. The FGDs and stakeholder consultations indicated the limited adoption of improved technologies and crop varieties while dominance of local landraces for both major and minor crops, including bean and amaranth. In rice, Jumli Maarsee, a landrace was the most dominant. Majority of the farmers were growing different Jumli Maarsee as they called *Jumli Maarsee (red), Jumli Maarsee (black), Jumli Maarsee (white), Jumli (Darime)* while the adoption of improved rice varieties such as Chandannath-1, Chandannath-3, Lekali-1 and Lekali-3 was very low compared to the local landrace. According to farmers and DADO officials, about 90% of the total rice area was covered by Jumli Maarsee. A study carried out by IRRI-NARC also showed about 12% of the rice area covered by improved varieties in Jumla district

(Gautam et al 2013, Velasco et al 2013). Though Jumli Maarsee is highly susceptible to rice blast disease, the farmers still prefer to grow this landrace due to its cold tolerance, easy threshability, better taste, price and its nature of volume expansions while cooking than improved varieties.

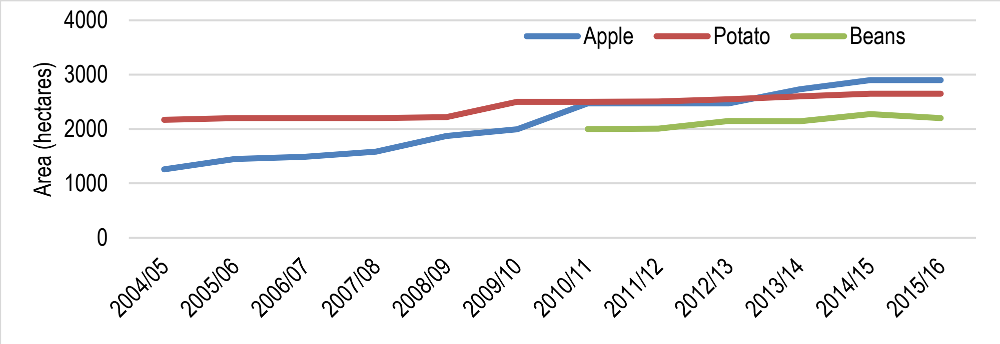

Figure 5. Area under major cash crop production in Jumla district.
Source: MoAD 2016, DADO Jumla 2016.

In maize, farmers grow only the landraces that include *Dabli, Tiyase, Murali, and Pahelo Sano*. The improved varieties so far tested in the past could not be successful under Jumla conditions. In wheat, local cultivar *Haanse* was the dominant one, covering about 80% of the wheat area. Improved varieties such as WK-1204, Dhawalagiri and Annapurna series were grown in the remaining areas. According to the farmers, Annapurna series had a problem of germinating (poor dormancy) during rainy season resulting into loss of the crop. The farmers also perceived taste of local cultivar better than the improved variety WK-1204. Furthermore, availability of quality seed of improved varieties was limited. All these factors were responsible for the dominance of wheat landrace over improved varieties in the district. In barley, landrace *Chawali* was the most popular in both irrigated and rainfed lands in the winter seasons. According to the farmers, it is tasty and early maturing with small and white colored grains. Some farmers in the higher altitudes grow *Lekali* landrace which is late maturing and has yellow colored bold grains. In finger millet, landraces such as *Dabli, Dalle (Murali) and Kaalo Kodo* were grown. The farmers and DADO officials expressed that the trend of production of rice, maize and finger millet is almost similar to that of the past years while it is declining for wheat and increasing for barley. The status of diversity and dominance of major mountainous cereal crop varieties as perceived by the farmers and DADO officials is given in Table 1.

Table 1. Varietal diversity and dominance of major mountainous cereal crops in Jumla district, 2016*

Crop	Varieties grown	Production season	Productivity (t/ ha)	Production trend
Rice	*Jumli Maarsee* (90%), Chandannaath-1 (6%) and Chandannaath-3 (3%), Lekali-1 and Lekali-3 (1%)	May-November	2.0 Mt	Same
Maize	*Dabli* (more than 50%), *Murali, Tiyase,* and *Pahelo* (50%)	March-October	2.5 Mt	Same
Wheat	*Haanse* (80%), WK-1204 (16%), Dhawalagiri (3%), Annapurna 1, 3, and 4 (1%)	November-July	1.4 Mt	Decreasing
Barley	*Chawali* (95%) and *Lekali* (5%)	November-June	1.2 Mt	Increasing
Finger millet	*Dabli, Dalle, Kaalo* (100%)	May-October	1.0 Mt	Same

**The information is based on Focused Group Discussion with farmers and interaction with District Agriculture Development officials.*

Naked barley, grown in similar environment as that of barley and wheat, was rarely grown and there were no distinct cultivars. Naked barley is mainly consumed as *saatu* (roasted grain flour). Now eating *saatu* is getting less because of easy availability of readymade imported foods like noodles and biscuits in the market and it might also have further affected the production of this crop in the district. In proso millet, *Dudhe Chino* (white grain colored) and *Raato Chino* (red colored) are the major landraces. *Dudhe* was preferred due to its grain color as well as easy threshability. In foxtail millet, *Raato Kaaguno (red colored grain), Pahelo Kaaguno (yellow colored grain) and Seto Kaaguno (white colored grain)* were the major landraces and usually grown in mixed or inter-cropping system with finger millet. Similarly, in buckwheat, *Bhadule/Tite Faapar* (tartary type), also consumed as leafy vegetable, and *Bhate/Kise/Mithe Faapar* (sweet type), also used as bread or grain flour paste, were the major landraces. In amaranth, *Jhaduwa Maarsee, Laal Maarsee, Laadi Maarsee* were the major landraces and mostly consumed as snacks and used for religious purposes. The minor cereal crops demand more labor for production and processing operations and have lower yields than the major cereals. Also, the production season and environment (land type and climatic suitability) of these minor crops are overlapped with the major cash crops (bean, potato and apple). As a result, these minor crops are gradually being replaced by these cash crops.

Bean are one of the major traditional crops grown in Jumla and it has number of landraces. The most common landraces include *Kaalo Maale* (black colored), *Raato Maale* (red colored) and *Seto Maale* (white colored) and mixed colored bean. With the increased demand and easy access to the market, bean offers a good source of income to many farmers in the district. Similarly, apple is one of the major high value cash crops and with the increased support from various organizations and improved market access, the production of apple is gradually increasing in the district. Potato and other vegetable production are also increasing gradually due to their increasing market demand. The status of traditional minor crops and major cash crops based on the perception of farmers and agricultural technicians is summarized in the **Table** 2.

Table 2. Varietal diversity and dominance of minor cereal crops, amaranth, apple, and bean in Jumla district, 2016*

Crop	Varieties grown	Production Season	Productivity (t/ ha)	Production trend
Naked barley	Local (100%)	December-July	1.0 Mt	Decreasing
Proso millet	*Dudhe* (white coloured), *Rato/Haade* (100%)	May-Sep	0.8 Mt	Decreasing
Foxtail millet	*Raato Kaguno, Pahelo Kaaguno, Seto Kaaguno* (100%)	May-October	0.8 Mt	Decreasing
Buckwheat	*Bhadule/Tite* (60%), *Mithe* (30%), *Bhate/Kise* (10%)	May-October	1.0 Mt	Decreasing
Amaranth	*Jhaduwa Marshe, Laal Marshe, Ladi Marshe*	June-October		Decreasing
Bean	*Kaalo Male* (30%), *Raato Male* (20%), *Seto Male* (15%), Small black (15%), Mixed colored (20%)	May-October		Increasing
Apple	Red, Royal and Golden Delicious (80%), others (20%)	Aug-October	200 kg/plant	Increasing

**The information is based on focused group discussion with farmers and interaction with District Agriculture Development Officials.*

Key factors influencing the traditional crops in the district

The interactions made with the stakeholders and the available data indicate an alarming situation of traditional mountain crops particularly proso millet, foxtail millet, buckwheat and naked barely in the district. The production of these crops in recent years is rapidly shrinking than in the past. The value that these crops possess for food and nutrition security including improving economic opportunities and resilience of the mountain communities in the changing environment has largely been ignored or not taken into account for their promotion. The key factors influencing the diversity of mountain crops in Jumla district are described in the sections below and summarized in **Table** 3.

Physical factors: Improved road connectivity and access of food by the farmers

Prior to the opening of the road track (before 2007) in the district, majority of the people used to grow traditional crops and rely on the food produced by themselves for the livelihoods. After the construction of road, local economy started transforming rapidly with transformation of the roadside settlements into the markets that enhanced the accessibility of imported foods (rice) and other goods and services among the local people (Republica 2017). As a result, people no longer had to rely on their own production for household food needs which ultimately affected in production of traditional crops in the district. On an average, about 334 kilogram (kg) of rice is purchased by the households in Jumla district (Palikhey et al 2016).

Improved road connectivity and availability of preferred rice varieties (brands) in the locality even seem to have an effect on the supply of subsidized rice by the Nepal Food Corporation (NFC) as the available data of rice supply by NFC reveals a declining trend in the district (**Figure** 6).

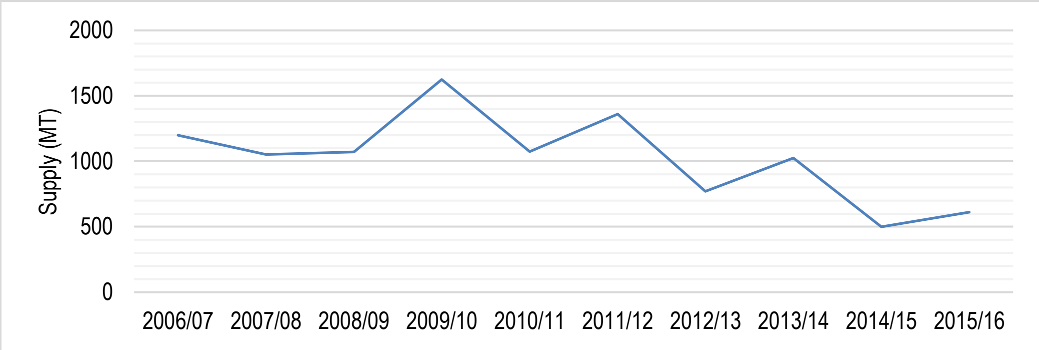

Figure 6. Trend of rice supply from Nepal Food Corporation in Jumla district.
Source: NFC, Kathmandu 2016.

Socio-cultural factors: Changing food habit and social taboos
With improved access to the market and goods, the consumption of local cereals and grains are increasingly being replaced by the imported food (rice), influencing both the food habit and food system (Happychuk et al 2014). People have higher preference of rice over local grains because of the taste as well as decreased drudgery in processing, preparing and cooking rice as compared to *roti* (wheat bread) and others. Moreover, it is not only the superior taste and lower drudgery but also the social perception or taboos that also consider eating rice superior than eating other traditional crops. Although previous studies have found that increasing incomes lead to the diversification of diets away from the traditional dominance of rice, this is not the case in Jumla, where rising incomes seem to have corresponded with a greater consumption of rice (Happychuk et al 2014). The value of rice consumption is linked with social status in the district, and people eating rice are believed to be rich with an ability to afford the imported rice (Happychuk et al 2014) while those consuming minor traditional cereal crops are supposed to be poor. Such kind of changing food habit and social taboo has also discouraged farming and consumption of traditional minor crops in the district.

Institutional and policy factors: Imbalance of public subsidies and support programs
The DADO, Jumla is one of the key public institutions providing various supports to the farmers for agricultural development. The supports such as subsidies, supports on seeds and other technologies, including equipment/machineries, production and marketing practices are, however, mostly concentrated towards cash crops, including apple, bean, potato, and other vegetables while the support programs and investments on traditional minor crops are very limited. DADO, Jumla has a vision of promoting export of apple and bean and improving production and productivity of food crops for enhancing the food-security of the people. DADO is executing self-reliance program on apple in the entire district and larger part of its resource is invested for promotion of apple in the district. Similarly, local institutions such as farmers' groups/cooperatives/seed producers groups including value chain/market networks developed by DADO are also effective for the major cereals and high value cash crops while minor crops are deprived of such supports. It is not only the public agricultural extension agency but agricultural research stations such as Agriculture Research Station (ARS) at Vijayanagar, another public agricultural agency located in the district headquarter, has also poor focus on traditional minor crops. Presently minor traditional crops receive no technical support, subsidies and economic incentives for their production, marketing and use.

Economic factors: Higher demand and profitability of cash crops
As stated before, improved road connectivity, market access and infrastructural development along with the increased support from the public sectors have been instrumental in expansion of apple and bean farming in the district. Awareness, popularity and demand of these local organic products are also increasing across the country. Additionally, apple and bean have higher productivity as well as profits compared to other traditional minor crops (Palikhey et al 2016, Atreya and Kafle 2016) which has attracted and encouraged farmers to shift from farming of traditional minor crops to these cash crops including potato and other vegetables. Besides, there is also a common practice of exchanging one kilogram (kg) bean with two kg of rice while there is no any significant demand or practice of such exchanging for minor cereal crops. Happychuk et al (2014) also found higher involvement of

people in cash crops production in the district as compared to the traditional cereal crops due to their higher demand and profit compared to the traditional local crops. Hence, higher market demand and profitability of cash crops provided perverse incentives for the production and consumption of traditional underutilized crops (Gauchan et al 2020).

Table 3. Factors influencing cultivation and consumption of traditional mountain crops in Jumla

Factors	Specific sub-factors	Impact on production and use of local crops
Physical factors	• Improved road conditions, market networks, and access to food (goods and services) • Transformation of rural settlements into markets and increased opportunities of non-farm employment	• Farmers are no longer involved in production of traditional minor crops which they used to grow in the past for subsistence • Increased reliance on imported foods and change of food habits
Socio-cultural factors	• Increased use of modern/exotic food culture with open economy and connectivity • Derogatory social conception towards production and consumption of minor crops	• Increasing demand for exotic/processed foods resulting in less need for local crop production • Declining use of local crops in local food culture and cultivation • Less motivation and interest to cultivate traditional minor crops
Institutional and policy factors	• Low or no research and development (R & D) investment for minor crops • No subsidy and support for production, processing and value chain development of minor local crops	• Declining area due to limited access to improved varieties and technologies of minor crops • Declining interest and motivation among farmers for production and marketing of traditional minor crops
Economic and market factors	• Better price and profitability from cash crops such as apple, bean and vegetables • Lack of market demand for the traditional minor crops • Low productivity and profitability of the traditional minor crops	• Shifting of farming from traditional minor crops to commercial cash crops • Decline in production and gradual loss of traditional minor crops (crop diversity)
Technological factors	• Lack of improved varieties, quality seeds and package of practices for traditional minor crops • Requirement of more labor and energy for production and processing of traditional minor crops including cooking as food • Processing technologies are not available	• Low productivity of traditional minor crops resulting in declining area under local crops • Higher cost and drudgery in cultivation and processing (including cooking) of traditional minor crops resulting in less interest for farming
Environmental/ Bio-physical factors	• Higher incidence of disease and pests • Higher incidence of drought (irregular rainfall), hailstorms, frost etc.	• Reduced cultivation of traditional minor crops • Increasing crop failure and low yield of crops

Technological factors: Low productivity and lack of improved technologies

Minor crops in general have lower yields than the major cereal crops. Furthermore, improved technologies such as improved seed/saplings, value addition, and processing, including technical supports are more available for major cereals and cash crops like apple and bean than for minor cereal crops which has also played a role to have less attention of farmers towards the minor crops. Minor cereal crops such as proso millet and foxtail millet demand more labor for production and processing than the cash crops. Additionally, there is also a lack of labor in the villages (due to out-migration and more employment in non-farm sectors) as well as appropriate processing equipment and farmers feel tedious to perform processing operations of minor cereal crops manually which has also discouraged its farming among the farmers.

Environmental/bio-physical factors: Pest and diseases/climatic stresses

Traditional mountain crops are well adapted to the local environment and environmental factors are not much of problematic to the local minor crops. Yet, there is increasing incidence of occurrence of heavy and erratic rainfall, hailstorms, disease and pest incidences and predators (such as birds, livestock and other wild animals) which cause production losses of minor local crops. Happychuk et al (2014) also reported environmental and bio-physical factors as one of the major factors for declining production of traditional crops including the changes in food habits in Jumla district. The key factors influencing traditional crops diversity in Jumla has been summarized in **Table** 3.

DISCUSSION

Nepal is though rich in biodiversity, ensuring food security and improving resilience of farmers to climate change are the major challenges for the country. The impacts of climate change are increasingly visible. Nepal is already experiencing water deficit during 4-5 months in the non-monsoon season and the situation is expected to worsen further with the global warming. Similarly, out of total 77 districts, 32 districts are still food deficit while 26 districts in remote areas are food insecure and 41% of the population are deprived from consuming the recommended minimum calories daily. The highest prevalence of hunger is in the Far- and Mid-Western Hill and Mountain regions of the country (MoAD 2016a). Almost 60% of households are food insecure, and the prevalence of stunting and underweight in children of aged below 5 year is 53% and 36%, respectively, which is significantly higher than national figures (which are 41% and 29%, respectively) and neglect and underutilization of traditional food crops is the prominent reason for such high nutrition insecurity in the mountains (Adhikari et al 2017). Nepal has already made its commitment to undertake Zero Hunger Challenge (ZHC) of building the 'world without hunger' declared by the Rio+20 Conference on Sustainable Development and also developed national action plan to end hunger, food insecurity and malnutrition by 2025 (MoAD 2016b) and it will not be successful unless the government pays focus on ensuring sustainable and improved local food production and consumption across the nation.

Traditional mountain crops providing food and nutrition act as a safety-net to the mountain people. They are well adapted to marginal land and local environment as well as constitute valuable nutritional elements (eg protein, fat, carbohydrate, vitamins and minerals), which are required for a healthy living. These crops are nutritionally rich for example, the crops like proso millet, foxtail millet and bean constitute higher protein, fat, and minerals than the staple crops. Similarly, finger millet is rich in calcium and iron content while naked barley and amaranth have higher carbohydrate and fat contents, respectively than the staple crops (DFTQC 2012, Joshi et al 2020b). However, public policies and program have not adequately recognized and sensitized the value of these traditional mountain crops including NUCs which has led to a decline in production and consumption of these crops in the mountain areas (Adhikari et al 2017, Joshi et al 2019) like Jumla district. Similarly, due to improved access of imported foods along with limited promotion of the local foods, people even in the mountain areas have rapidly built the food habits that are unsustainable and unhealthy. Most of the consumers in food deficit areas of Nepal have higher preference towards rice which has also led to the neglect of production of other traditional crops (eg millets, oats, barley, buckwheat etc) (MoAD 2016b). Per capita production of NUCs is extremely low compared to wheat, rice and maize in Nepal. Similarly, the contribution of NUCs such as millets, barley, buckwheat, black gram, lentils, red gram, horse gram and bean, to annual per capita food consumption is very low (8%) compared to rice, wheat and maize crops (62%). If we take account of only millets, barley, buckwheat, black gram and horse gram, the contribution remains only 3.84% (Adhikari et al 2017). This also reveals a lower food or dietary diversity among Nepalese people. This study also revealed rapidly changing food habit of the local people including increased reliance of people on imported food while neglect of the local crops in the local production as well as food system and the key factors behind such changes happening in Jumla. Although this study is confined to Jumla, similar practices that threaten the local production and food system could have also taken place in other parts as well with the recent developments in the country. It would be difficult for a country to achieve food and nutrition security (zero hunger) if it does not timely and adequately recognize and promote the value of locally adapted crops or resources. Raising awareness, facilitating technological innovations and encouraging the people in farming of the local crops along with their greater inclusion in local food system as well as developing their value chain and market would be vital for promotion of these crops in the mountainous regions (Gauchan et al 2019). Additionally, traditional mountain crops including NUCs can play a vital role not only to improve the food, nutrition and income security, but also to enhance biodiversity and resilience of people from various shocks in the mountain areas. Therefore, the government and the stakeholders should focus on mainstreaming these crops into national policies and programs and develop mechanisms to enable farmers ensure sustainable food, nutrition and income from traditional mountain crops.

CONCLUSIONS AND RECOMMENDATIONS

Traditional mountain crops are crucial for food and nutritional security as well as income generation of the farmers in the mountain regions. They are adapted to adverse climatic environments like cold and drought and can grow well even in marginal lands and low external inputs. Therefore, they are vital for the survival/subsistence of the people even under harsh conditions. Traditional mountain crops used to be the key source of food and nutrition to the people in the past but these crops particularly proso millet, foxtail millet, buckwheat in recent years are declining due to influence of physical, socio-cultural, institutional/policy, economic, technological and environmental/bio-physical factors. Local people are increasingly becoming dependent mostly on imported food (rice) which has not only changed the perception and food habit of the people, but also slowly destroying the local food system. Additionally, public policies, programs and supports are mostly focused towards promotion of few cash crops like apple, bean and vegetables while the value of the traditional crops grown since many generations are yet not adequately recognized. If such neglect of these crops continues, then it may cause irretrievable loss of the invaluable crop germplasm and local food diversities/system in the future and may place food production/security and ecosystem at risk of various shocks and the changing environment. Therefore, in order to revive and promote these traditional mountain crops and improve resilience of the farmers to various shocks, the following measures need to be taken seriously.

- Traditional mountain crops should be mainstreamed in the national policies, programs and priorities should be given for their conservation, use and promotion.
- Institutional mechanisms need to be developed and strengthened for technology generation, extension, value addition/processing/product development, and market development of mountainous crops.
- Awareness raising/sensitization is necessary for changing the perception and food habit of the people and integrating/promoting traditional mountain crops into food systems.
- Value chain and market development of traditional minor crops linking and branding it with organic and mountainous production environment is essential to promote production, marketing and consumption.
- Agricultural subsidy and other support distribution from the public agencies need to be revised/revisited. The subsidy supports should also take account of small and marginal farmers and minor crops. Rather than providing subsidy (transportation) for food imports to the remote mountainous areas, if it is also used for purchase, value addition and supply of traditional mountainous crops (from the rural mountainous areas to urban areas), then it will help to revive and scale up the farming and use of traditional crops in the mountain regions.

ACKNOWLEDGEMENTS

The authors would like to thank farmers, and other stakeholders such as DADO Jumla, ARS, Jumla, NFC-Jumla and Kathmandu, WFP Jumla, LI-BIRD Jumla, local traders, and other key informants for the valuable information, and support.

REFERENCES

Adhikari L, A Hussain and G Rasul. 2017. Tapping the potential of neglected and underutilized food crops for sustainable nutrition security in the mountains of Pakistan and Nepal. Sustainability **9:**291.

Alcázar JE. 2006. Protecting crop genetic diversity for food security: political, ethical and technical challenges. Nature Reviews Genetics **6**:946-953.

Atreya PN and A Kafle. 2016. Production practice, market and value chain study of organic apple of Jumla. The Journal of Agriculture and Environment **17**:11-23.

Bajracharya J, MR Bhatta and S Silwal. 2013. Review of intra-specific diversity of target crops in Nepal. Annex 1, Project document. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Bioversity International, NARC, DoA, LI-BIRD.

Bajracharya J, RB Rana, D Gauchan, BR Sthapit, DI Jarvis and JR Witcombe. 2010. Rice landrace diversity in Nepal: Socio-economic and ecological factors determining rice landrace diversity in three agro-ecozones of Nepal based on farm surveys. Genetic Resources and Crop Evolution **57**(7):1013–1022.

Baniya BK, PR Tiwari, D Pandey and J Bajracharya. 2003. Field study of two barley landraces of Jumla. **In:** On-farm management of agricultural biodiversity in Nepal (BR Sthapit, MP Upadhyay, BK Baniya, A Subedi and BK Joshi, eds). Proceedings of a National Workshop, 24-26 April 2001. NARC, LI-BIRD, IPGRI, Lumle, Nepal; **pp**.127-135.

DADO. 2010/11-2015/16. Annual Report (2010/11 to 2015/16). District Agriculture Development Office, Jumla

DFTQC. 2012. Food Composition Table for Nepal. Department of Food Technology and Quality Control, National Nutrition Program, Ministry of Agriculture Development, Government of Nepal, Kathmandu.

FAO, 1999. What is Agrobiodiversity? United Nations Food and Agriculture Organization (FAO), Rome, Italy.

FAO. 2014. Management of crop diversity: Key practices for DRR implementers. Food and Agriculture Organization.

Frison EA, IF Smith, T Johns, J Cherfas, PB Eyzaguirre. 2006. Agricultural biodiversity, nutrition and health: Making a difference to hunger and nutrition in the developing world. Food Nutr. Bull. **27**:167–179.

Gauchan D and U Khanal. 2013. Review of socioeconomic, institutional and market dynamics of agobiodiversity in mountain ecosystems of Nepal, Annex 1, Project document. **In:** Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. GEF/UNEP, Bioversity International, NARC, DoA, LI-BIRD.

Gauchan D, N Maxted, M Cole, M Smale, MP Upadhyaya, BK Baniya, A Subedi and BR Sthapit. 2005. Policy incentives for conservation and the sustainable use of crop genetic resources in Nepal. **In:** On-farm conservation of agricultural biodiversity in Nepal Volume II. Managing diversity and promoting its benefits (BR Sthapit, MP Upadhyay, PK Shrestha and DI Jarvis, eds). Proceedings of the Second National Workshop 25–27 August 2004, Nagarkot, Nepal; **pp**. 135-148.

Gauchan D, B Bhandari, R Gurung, BK Joshi and D Jarvis. 2019. Value chain development of underutilized food crops for nutrition sensitive agriculture in the mountains of Nepal. **In**: Proceeding 5th International Agricultural Marketing Conference, Kathmandu, June 4-5, 2018. Nepal Agricultural Economic Society (NAES), Ministry of Agriculture and Livestock Development (MoALD), FAO, KISSAN-2, USAID, Nepal.

Gauchan D, BK Joshi, B Bhandari, N Pudasaini, R Gurung, KH Ghimire and KK Mishra. 2020. Incentive measures for agrobiodiversity conservation and use. **In**: Good Practices for Agrobiodiversity Management (Joshi BK, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gautam S, HK Panta, ML Velasco, YN Ghimire, D Gauchan and S Pandey. 2013. Tracking of Improved Rice Varieties in Nepal. Country report for rice component of the project "Tracking of improved varieties in South Asia". Monograph. International Rice Research Institute, Philippines.

Happychuk N, E Palikhey, L Lama, S Sthapit and S Shukla. 2014. Reacquiring a taste for diversity: Changing food habits, their causal factors, and the value of dietary diversity in Jumla, Nepal. International Journal on Biodiversity Issues **4**. (Abstract).

ICIMOD. 1987. Mountain Crop Genetic Resources. Report of the international workshop on mountain agriculture genetic resources. International Centre for Integrated Mountain Development, Kathmandu, Nepal.

Jarvis DI, C Padoch and HD Cooper. 2007. Biodiversity, agriculture and ecosystem services. **In**: Managing Biodiversity in Agricultural Ecosystems (DI Jarvis, C Padoch and HD Cooper, eds). Bioversity Int'l, Columbia Univ. Press; **pp**.1-12.

Jarvis DI, T Hodgkin, AHD Brown, J Tuxill, IL Noriega, M Smale, and B Sthapit. 2016. Crop Genetic Diversity in the Field and on the Farm: Principles and Applications in Research Practices. Yale university press, New Haven and London.

Jarvis DI, T Hodgkin, BR Sthapit, C Fadda, IL Noriega. 2011. A heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. Critical Reviews in Plant Sciences **30**(1-2):125-176.

Joshi BK. 2004. Rice gene pool for mid and high hills and its conservation in Nepal. **In**: Agricultural Research for Enhancing Livelihood of Nepalese People (BK Joshi, SL Joshi and KP Paudyal, eds). Proceedings of 2nd SAS-N Convention, 30 July - 1 Aug 2003, Kathmandu; **pp**. 252-264.

Joshi BK, AK Acharya, D Gauchan and MR Bhatta. 2017a. Agrobiodiversity status and conservation options and methods. **In**: Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Proc. 2nd National Workshop, 22-23 May 2017; NAGRC, FDD, DoA and MoAD; Kathmandu; **pp**. 21-38.

Joshi BK, MR Bhatta, KH Ghimire, P Chaudhary and D Singh. 2016. Mapping and measuring the flow and interdependence of plant genetic resources. **In**: Implementing the International Treaty on Plant Genetic Resources for Food and Agriculture in Nepal: Achievements and Challenges (BK Joshi, P Chaudhary, D Upadhya and R Vernooy, eds). LIBIRD, Pokhara; NARC, MoAD, Kathmandu and Bioversity International, Rome; Nepal; **pp**. 28-52.

Joshi BK, N Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020a. Agrobiodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33.

Joshi BK, P Ojha, D Gauchan, KH Ghimire and HB KC. 2020b. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, R Shrestha, IP Gautam, AP Poudel and TP Gotame. 2019. Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Joshi BK, R Vernooy and P Chaudhary. 2017b. Crop interdependence, adaptation to climate change and the multilateral systems of access and benefit sharing: The case of Nepal. Indian Journal of Plant genetic Resources **30**(3):210-217. **DOI**: https://doi.org/10.5958/0976-1926.2017.00026.2

MoAD. 2004/05-2015/16. Statistical Information on Nepalese Agriculture (2004/05 to 2015/16). Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division, Statistics Section, Singhadurbar, Kathmandu, Nepal.

MoAD. 2016a. Agriculture Development Strategy (ADS) 2015 to 2035 Part: 1, Government of Nepal, Ministry of Agricultural Development, Singhadurbar, Kathmandu.

MoAD. 2016b. Nepal: Zero Hunger Challenge, National Action Plan (2016-2025). Ministry of Agricultural Development, Singhadurbar, Kathmandu, Nepal.

MoFSC. 2002. Nepal Biodiversity Strategy. His Majesty's Government of Nepal/Ministry of Forests and Soil Conservation, HMG, Nepal, Supported by Global Environment Facility and UNDP.

Padulosi S, J Thompson and P Rudebjer. 2013. Fighting Poverty, Hunger and Malnutrition with Neglected and Underutilized Species (NUS): Needs, Challenges and the Way Forward. Bioversity International, Rome.

Padulosi S, V Heywood, D Hunter and A Jarvis. 2011. Underutilized species and climate change: Current status and outlook. **In:** Crop Adaptation to Climate Change (SS Yadav, R Redden, JL Hatfield, H Lotze-Campen, A Hall, eds). Blackwell Publishing Ltd, Oxford, UK; **pp**. 507–521.

Palikhey E, SR Sthapit, S Gautam, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline survey report III. Hanku, Jumla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.

Paudyal CL, PR Tiwari, JD Neupane and DP Devkota. 1998. Strengthening the scientific basis for in- situ conservation of agrobiodiversity: Findings of in-situ selection exercise in Jumla. NP Working paper No. 3/98 NARC, LIBIRD and IPGRI.

Republica. 2017. Karnali highway: The road that transformed Jumla. Republica national daily, 27 July 2017.

Sthapit BR and S Padulosi. 2011. On-farm conservation of neglected and underutilized crops in the face of climate change. **In:** On-farm Conservation of Neglected and Underutilized Species: Status, Trends and Novel Approaches to Cope with Climate Change (S Padulosi, N Bergamini and T Lawrence, eds). Proceedings of the International Conference, Friedrichsdorf, Frankfurt, 14-16 June, 2001. Bioversity International, Rome; **pp**. 31-48.

Upadhyay MP and BK Joshi. 2003. Plant Genetic Resources in SAARC Countries: Their Conservation and Management: Nepal Chapter. SAARC Agriculture Information Center; **pp**. 297-422.

Velasco ML, TW Tsusaka and T Yamano. 2013. Tracking of Improved Varieties in South Asia (TRIVSA). TRIVSA Synthesis Report on Rice. International Rice Research Institute (IRRI). Los Banos, Philippines.

Wood D and JM Lenne. 1997. The conservation of agrobiodiversity on-farm: questioning the emerging paradigm. Biodiversity and Conservation **6:**109-129.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project; Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Rescue to Registration: A Case of Bean Landraces from Dolakha, Nepal

Niranjan Pudasaini, Deepa Singh Shrestha, Devendra Gauchan, Brinda Linkha and Santosh Shrestha

ABSTRACT

Nepal ranks 25th and 11th positions in biodiversity richness in the world and Asia, respectively but it is facing rapid loss of crop diversity due to socioeconomic transformation, modernization in farming system and climate induced stresses. Many local crops and landraces are often neglected and underutilized despite of having unique use values and varietal traits. Various on-farm agro biodiversity management tools and practices have been developed and adopted to identify, conserve and promote local plant genetic resources globally. This article demonstrates the utilization of different participatory tools in the identification of two rare common beans from Jungu, Dolakha and strategies in mainstreaming into national seed system. This article aims to shares the insights of utilizing the combination of various participatory tools of agro-biodiversity management in real ground experience and further up to influencing the policy. Two rare common bean landraces viz. *Pahenlo Simee* and *Khairo Ghiu Simee* were identified as rare using the four-cell analysis and were further characterized, promoted, disseminated and mainstreamed using other on-farm agro-biodiversity participatory tools. Analyzing the local context, multiple participatory tools were sequentially packaged and practiced generating cumulative results from 2014 to 2019. The process has been effective to rescue two rare local landraces that were on the verge of extinction and promote them up to registration process at the national level for commercialization and enhanced benefit sharing to farming communities.

Keywords: Agro biodiversity, bean landraces, conservation, landrace promotion, mainstreaming, participatory tools

INTRODUCTION

Nepal ranks 25th and 11th positions in biodiversity richness in the world and Asia, respectively which is under threat due to different abiotic factors such as agriculture modernization, migration and climate change. However, local crop conservation and promotion is gaining momentum globally as its contribution to food and nutritional security and climate change adaptability is being widely recognized. Wise use of local plant genetic resources is considered as a dependable instrument to combat with unpredictable climatic changes. Farmers are managing local agro biodiversity on their particular niche promoting on-farm conservation and natural evolution of plant genetic resources (Jarvis et al 2004, Bezancon et al 2009). Farmer's preferences on farming system changes overtime with socio-economic transformation and with increasing access on modern farming technologies. As a consequence, many traditional crops or varieties are being neglected and underutilized. Increasing access to modern varieties, food preference change, and migration-induced labour shortage including poor incentives for management of on-farm agro-biodiversity has also exacerbated underutilization of local crop genetic diversity. Though farmers are master on utilizing local crop genetic diversity, sometimes acquitted negligence or lack of attention might also lead to loss of certain crops or varieties at a local level. Limited research and crop development programme on local crops with inadequate policy support are also responsible for underutilization of local crop diversity in Nepal. It is claimed that half of the total local landraces diversity has been extinct from Nepalese farming system (Joshi et al 2017). In the race of securing higher yield, many traditional crops and varieties are being neglected by farmers deliberately or sometime unintentionally. Major cereals, cash crops and modern varieties focused regular development programmes are targeted to achieve higher yield by compromising diversity rich solutions. The situation has resulted in undervaluing those unique local crops landraces which used to be favoured and dominant once at a particular site.

Over the last few decades, a range of actions or practices has developed and become available to help farmers and farming communities continue to benefit from the maintenance and use of local crop genetic diversity in their production systems (Sthapit et al 2006, Jarvis and Hodgkin 2008). Most of the actions or tools are small in scale and site and crop-specific, resulting in from a local evaluation of farmers' constraints to their current use of local crop genetic resources. Depending on status, constraints and opportunities of particular crop diversity, interventions should be designed and implemented addressing the local situation. A systematic bottom up approach of diversity assessment, issue-specific planning and execution can bring tangible result.

This article covers a case story of rescue and promotion of endangered but two rare local landraces of common bean (*Phaseolus vulgaris*) of Dolakha via utilizing combination of multiple agrobiodiversity management tools. This is an outcome of the UNEP GEF Local Crop Project (LCP) implmented in Nepal during 2014-2019. The project focused on the mountain districts of Nepal targeting eight traditional underutilized mountain crops including amaranth, bean, buckwheat, barley, finger millet, foxtail millet, proso millet and high altitude rice. Two endangered local common beans namely *Khairo Ghiu Simee* and *Pahenlo Simee* were identified and rescued in 2015 by LCP project. These local landraces were characterized, evaluated and promoted them for their commercialization and enhanced benefit sharing to local communities in the last five years (2014-2019). In 2014 project learned that *Khairo Ghiu Simee* was only grown by single household by Mr Chhatra Bhadur Jirel in Jungu village (Linkha and Pudasaini, 2019) and *Pahenlo Simee* by few households despite their strong local farmers' preference and production suitability. These two local bean landraces were locally adapted and very much preferred by farmers and local communities due to their multiple uses (both green vegetable pods and grain /*dal* purpose) and the possibility of cultivating in multiple seasons in a year. The article covers success story of these two endangered local farmers' bean varieties highlighting the use of various agro-biodiversity management tools as a package to bring cumulative results on rescuing, conservation and promotion in Dolakha, Nepal.

METHODOLOGY

The study adopted various globally recognized participatory approaches complemented with some good practices of agro-biodiversity management to identify, characterize and promote two endangered local landraces of beans. Various tools were practised sequentially to obtain cumulative results within 5 years of project implementation period as shown in **Figure** 1. The methods specifically focus on participatory diversity assessment tools. Various participatory Rural Appraisal (PRA)/ Rapid Rural Appraisal (RRA) tools were adopted during the process. Diversity Field School (DFS) was conceptualized and practised to make the process more disciplined and participatory (Joshi et al 2020). The specific process and steps for the case study is outlined below;

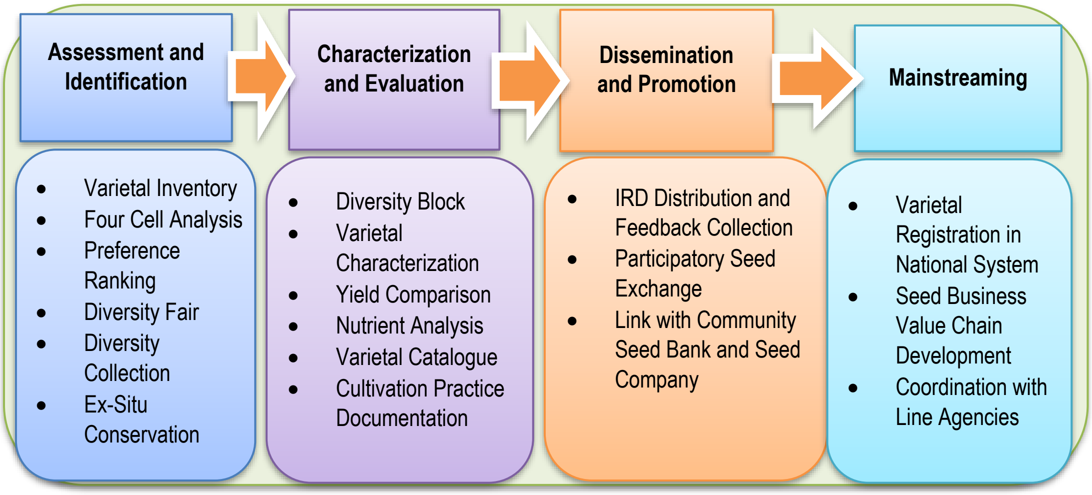

Figure 1. Methods and tools adopted during the chain of process.

Site overview

Jungu is a mountainous village, which lies in Gaurishankar Rural Municipality ward 1 and 2 in Dolakha district in the north central mountains of Nepal. The village lies in the north eastern region of the district and extends from 27^{0}50' to 27^{0}43' north, and 86^{0}8' to 86^{0}15' east, and has an altitude range of 950 m asl to 3000m-asl. The village covers an area of 33 square km, where 60% of the land area is forested, and only 40% of the land is cultivated (Jungu VDC Profile, 2009). Depending on the altitudinal gradient, the climate of Jungu VDC can be categorized as sub-tropical, warm temperate, or sub-alpine. The average annual temperature of Jungu ranges from a 3⁰C minimum to a 22⁰C maximum and the average annual rainfall is about 2000 mm per year.

An integrated farming system covering crops, livestock and agroforestry is the most common livelihood strategy in Jungu village. Farm land preparation, sowing, harvesting and threshing are done in a traditional way with human manual labour and traditional tools. Conventional terrace farming of local crops is the pillar of food security in the village. Besides crop and livestock production, livelihoods are often also supported by off-farm income sources, like seasonal migration for non-agricultural labours, foreign employments, and national services. Except for major cereal crops (rice, maize and wheat), almost all cultivated crops are local varieties/landraces. Informal seed sources make-up of 95% the local seed system, while a negligible contribution of formal seed sources exists for rice, maize, wheat and green vegetables such as cauliflower, pea, onion, and cabbage (Pudasaini et al 2016). The village possesses rich intra species diversity on rice, finger millet and beans. Beans are commonly known as "*Simee*" in Jungu and 68.9% of households cultivate 11 different types of bean varieties in their farm lands ranging from 1000 m asl to 2000 m asl altitude. In Jungu, beans are mainly cultivated for fresh vegetable purpose whereas grain consumption as "*Daal*" is aslo exist, however not common (Pudasaini et al 2016). Basically, *Khairo Simee* is preferred more for green pod consumption while *Pheylo Simee* is for dual propose of consumption (as a fresh vegetable of green pods and dried grain).

The devastating earthquake that hit Nepal on 25 April 2015 most severely impacted rural farm households particularly in remote and risk-prone mountainous regions in western and central Nepal (Gauchan et al 2018). Earthquake smashed Jungu village badly by both first devasting earthquake of 25 April as well as from the second earthquake that occurred in May 12, 2015. About 99% of the households were destroyed along with stored seeds and grains in the village. Farmers suffered from seed crisis in subsequent summer planting season (June-July 2015) and the case was more serious on minor crops like beans, buckwheat, barley, naked barley, leafy vegetables, etc. Those crops' seeds which farmers generally maintain in small amount/volume were more threatened due to miss placing and mixing during re-establishment of their shelters.

Diversity assessment and identification

Varietal inventory: Varietal inventory is useful to assess the varietal richness of any crops within a community (Sthapit et al 2006) and can be derived from FGD or baseline survey. Bean's varietal inventory was prepared from a series of ward/village level discussions in 2015 within the study area. Total 10 different local landraces of common bean were identified including local *Phanelo and Khairo Ghiu Simee.* Though baseline report by Pudasini et al (2016) have mentioned 11 different landraces, field validation and varietal catalogue confirmed 10 landraces of beans in Jungu, Dolakha (Gurung et al 2019).

Four cell aanalysis: Four Cell Analysis (FCA) tool as described by Sthapit et al (2006) was used to identify the status of beans landraces in Jugnu, Dolakha. Among the landraces of beans listed in FCA (**Figure** 2), *Pahenlo Simee* and *Khairo Ghiu Simee* were listed in cell C and cell D, respectively by the participants of FCA. Germplasm listed in cell C generally indicates a need of germplasm enhancement through participatory plant breeding, value addition, market links, recognition and awareness whereas germplasm listed in cell D shows a landrace is on the verge of extinction and hence needs ex-situ conservation initiatives (Sthapit et al 2006). *Khairo Ghiu Simee* was so rare that only one farmer Mr Chhatra Bhadur Jirel could provide only a seven seeds from the few pods he had saved containing approximately 10 seeds in December 2014.

Preference ranking: Participatory preference ranking is an important tool to identify farmers' preferences for specific crop varieties. Ranking matrix was used to get an overview of each landrace bean, its status and reasons for listed in different cells of FCA. FGD was organized and major preference determining traits were listed in a participatory way and ranked on a scale of low, medium and high preferences on different traits such as grain yield, fresh yield, grain taste, pod taste, cooking quality, market value, disease and drought tolerance. Among ranked 10 landraces, two local beans *Pahenlo Simee* and *Khairo Ghiu Simee* were ranked first (25 score) and second (23 score), respectiviely (**Table** 1).

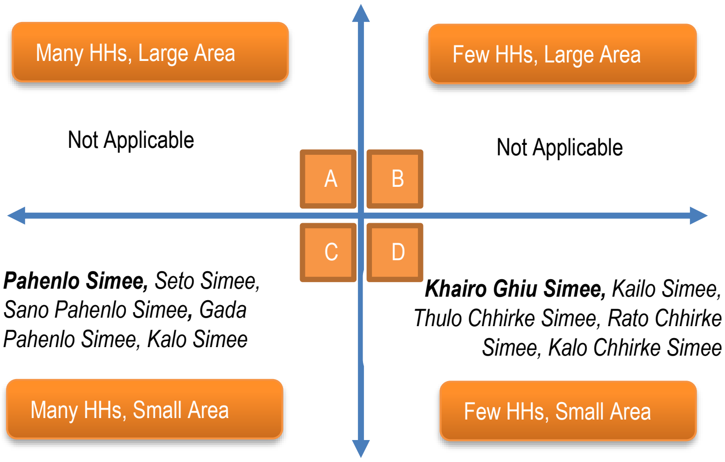

Figure 2. Variety level FCA chart of Jungu beans.

Table 1. Farmer's preference ranking on local bean landraces

Landrace name	Farmer-defined varietal traits of local beans									Rank
	Grain yield	Pod yield	Grain taste	Pod taste	Grain quality	Cooking quality	Market value	Disease tolerance	Drought tolerance	
1. Pahenlo	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**25**
2. Kaalo	2	2	1	1	2	2	1	3	3	17
3. Raato Chhirke	2	1	2	1	3	2	1	2	2	16
4. Khairo Ghiu Simi	**3**	**3**	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**23**
5. Seto	1	2	1	2	2	2	1	2	2	15
6. Kaalo Chhirke	2	1	2	1	2	2	1	2	2	15
7. Kailo	1	1	1	1	1	2	1	3	3	14
8. Saano Pahenlo	2	2	2	2	2	3	1	2	2	18
9. Gaadaa Pahenlo	2	2	2	2	2	3	1	2	2	18
10. Thulo Chhirke	1	1	2	1	1	2	1	3	3	15

Preference scale: 1- low, 2- medium and 3- high; Source: DFS Discussion 2016.

The further discussion in FGD identified that the farmers rarely saved seeds and obtained them from the neighbours. This guarntee of getting the seeds from neighbours lead to consuming all the fresh pods without saving them for seeds. This gradually shrinked the availability of seeds eventually leading to the most prefered landrace to become rare unintentionally. Combined results of FCA and ranking matrix were considered to work further on these two top ranked bean landraces.

Diversity fair and diversity collection: A diversity fair was organized on April 2016 at Junug, Dolakha site. The event was organized as a first social gathering and sensitize the value of agrobiodiversity to local community and stakeholders after devastating earthquake of April 2015. Local crop's diversity with associated knowledge were displayed and shared by 9 village ward level groups. In contrast, more information and accessions of local bean's diversity were collected from the diversity fair. Self-directed seed exchange and sharing of various crop varieties including these two beans were observed during the event. Diversity fair was helpful to demonstrate conservation status of all crops with their importance and use-value. Many seed accessions of project mandate crops were collected from diversity fair including 26 different landraces of beans. A group discussion was organised following the diversity fair to document information, cross-check and validate information on bean landraces in the area.

Among the twenty-six, existence of 10 landraces were confirmed and remaining 16 were locally used names of same landrace. Article covering the diversity fair can be acceseed in: http://himalayancrops.org/2016/06/03/local-crop-diversity-fair-in-jugu-dolakha-a-move-towards-normal-life-in-the-aftermath-of-devastating-earthquake/

Diversity blocks: A set of collected accessions of project mandate crops including these local Dolakha bean landraces were displayed in diversity block in 2016. Major objective of the diversity blocks were to demonstrate existing diversity of local crops, produce seeds for next season research trials. They were also used to characterized and evaluate useful traits of the local landraces. Diversity blocks were established and maintained by DFS participants and project team throughout the project period. Diversity blocks helped to regenerate seeds of rare landraces regularly and create awareness at a local level through diversity demonstration.

Ex-situ conservation: In the context of earth quake disrupted farming system and livelihood pace, 104 seed samples with passport data were sent to the Genebank for ex-situ conservation in February 2016. Two targeted bean landraces were also sent for the long-term conservation and was enlisted into the Genebank's database with the fulfillment of the requirements of database system. This was the first time that those beans were formally recognized and documented in a national recording system. These two landraces possess the unique accession number which is the permament number from the Genebank. The initiative helped to prevent loss of local crop diversity in one hand, on the other hand, all those diversity came into national pool of research and development plant genetic material.

Planning for the future interventions for the conservation and utilization of these landraces: Based on the results from the FCA and Diveristy fair, blocks, the project team with plant breeders developed a detail future intervention plans for the conservation and promotion of these beans. This unique approach of combinig farmers' knowledge and plant breeders' knowledge proved to be instrumental for this achievement. The design of detail protocols for documentation of qualitative and quantitative phenotypic characters, nutritional profiling and the establishment value seed chain were developed. Furthermore, the team designed the trial to fulfill the requirement for landrace registration under schedule D provision of National Seed Regulation 2013. DFS platform was used intensly to orient and train farmers for their good quality seed production and diversity deployement at local scale. Along with on-farm research activities, sensitization among local farmers for its conservation and utilization was conducted regularly.

Phenotypic characterization and evaluation

On-farm characterization trial: An on-farm characterization field trial covering 47 different landraces of local beans (including local diversity and accessions from the Genebank) was conducted in September 2015. The main objectives of the field trial were to evaluate and document morphological and agronomical characters and to test multiple varieties from other other location to increase diversity basket in project site. The on-farm trial was combined with the participatory varietal selection of the bean landraces which was achieved by farmer's (male and female) and researcher's voting to identify most preferred bean varieties. Comparing with all out-sourced landraces, farmer's voted *Pahenlo Simee* and *Khairo Ghiu Simee* as most preferred varieties considering bigger and softer pods size, higher number of pods per cluster and over all phenotypic performance. On-farm characterization trial indicated that both identified local bean landraces hold almost similar types of morphological charecters like plant height, leaf and pod shape size and days to maturity but grain size, shape and color are distinctive. Morphological charecters were again cross validated and refined with yield trial conducted in 2018 (**Table** 2).

Table 2. Morphological characteristics of two local beans

Character	*Khairo Ghiu Simee*	*Pahenlo Simee*
Plant height (cm)	376.16 ± 6.91	472.3 ± 15.72
Days to 50% flowering	50-60	40-50
Days to maturity	105-110	100-105
Immature pod colour	Normal green	Dull green
Mature pod colour	Creamy yellow with red pigments	Light yellowish white
Pod length* (cm)	17.44 ± 0.4	17.88 ± 0.54
Number of pods/cluster	3-4	3-4
Pod width* (cm)	1.08 ± 0.03	1.38 ± 0.05

Character	*Khairo Ghiu Simee*	*Pahenlo Simee*
Pod weight* (gm)	13.16 ± 0.31	21.94 ± 0.71
Pod/ plant* (gm)	830.72 ± 63.26	895.37 ± 65.76
Grain colour	Dark copper brown	Shiny yellow
Diseases		
Anthracnose	20-30% severity (Moderately susceptible)	20-30 % severity (Moderately susceptible)
Angular leaf spot	15% severity (Moderately field tolerant)	15% severity (Moderately field tolerant)

** Mean ± Standard error of mean. Source: Characterization trial 2015 and yield comparision trial 2018.*

Yield comparision trials: A replicated RCBD designed yield trial including 4 varieties (2 targeted local landraces and 2 released varieties) was conducted in 2018 in the study village. From this yield trials, both locally identified bean landraces were found equally promising in terms of yield attributing characters, number of harvest, and overall production as fresh vegetable and grain. The trial was carried out in two seasons which, however, demonstrated the differences in the yield attributing characters with the planting seasons recommending the winter season planting for these beans (**Table** 3). Observations also suggested that winter season planting is better for fresh vegetable pod production while summer season planting is suitable for grain production. Winter season planting can give fresh pod harvest during vegetable lean season (May-June) which fulfills household level demand as well as can tap market. The most useful and unique character of these two beans are that they can be grown for dual purpose in two planting seasons within a year.

Table 3. Yield comparision of two local beans with released varieties

	Winter season planting**		Summer season planting**	
Variety name	**Green pod (kg/Ropani)***	**Dry grain (kg/Ropani)***	**Green pod (kg/Ropani)***	**Dry grain (kg/Ropani)***
Pahenlo Simee	1020.9 ± 77.5	163.7 ± 5.9	712.5 ± 92.3	201.8 ± 27.5
Khairo Ghiu Simee	930.9 ± 67.5	134.8 ± 9.1	722.5 ± 76.7	179.2 ± 13
Trishuli Simee	727.6 ± 65.7	80.6 ± 6.8	449.9 ± 73.6	85.6 ± 8.5
Jayanti Simee	302.7 ± 30.3	78.3 ± 5.9	139.1 ± 24.7	74.9 ± 6.2

** Average production per Ropani ± Standard error of the mean (1 Ropani=508.5 meter square). ** Winter season means Feb - March planting and summer season means July - August planting. Source: Yield Comparison Trial 2018.*

Nutrition profiling: The nutrition profiling of these bean landraces were carried out and the protein content was at par with other landraces. The green pod and the dry seeds can be the good source of protien for the mountain population contributing to the nutrition security of the population (**Table** 4). The process helped to understand and highlight their importance in terms of nutritional use-value.

Table 4. Nutrient contents available in both local landraces of beans

Variety Name	Moisture %	Protein %	Fat %	Total ash %	Crude fibre %	Carbohydrate %	Total energy
Pahenlo Simee	8.28±0.35	20.17±0.24	1.32±0.1	3.6±0.04	4.58±0.08	62.03±0.46	340.76±1
Khairo Ghiu Simee	6.48±0.06	17.94±0.07	1.20±0.18	3.96±0.04	4.07±0.17	66.37±0.19	347.90±1

Source: Proximate nutrient analysis, Department of Food Technoloy and Quality Control, 2018.

Varietal catalogue: A comprehensive varietal catalogue was developed of the project site covering farmers' cultivated bean landraces including all project mandate crop's diversity with their agro-morphological characteristics, use values and quality photographs. The document has set a milestone on documenting local bean landraces inlcuding whole Himalayan crop's diversity available across the project sites with their unique traits and use value. The catalogue has helped to dessiminate information of all target crops including local beans in well structured way which can be utilized by researchers, students and development workers. The Traditional Mountain Crop Landraces in Nepal (Gurung et al 2019) catalogue can be accessed in http://himalayancrops.org/project/catalogue-of-traditional-mountain-crop-landraces-in-nepal/

Cultivation practice: Farmers-friendly (in local langauge) cultivation practices flyers of both beans were developed by combining traditional and scientific ways of farming method. Flyers consist of brief histroy, major agronomic charetoristics, step-by-step farming technology including common disease and pest identification and control measures. This complete package of cultivation practices document helped to popularize the varieties and also was found helpful for developing varietal registration catalogue. As this type of publication complements up-scaling process, bean seeds were disseminated with cultivation practice. Both flyers can be accessed in http://himalayancrops.org/publications/.

Dissemination and promotion

Participatory seed exchange: In order to increase access and exchange of local seeds within the community, a participatory seed exchange event was organized in the project site on December 2015. Total 35 different crops' 104 landraces were brought in the event. Among them 35 landraces including these two local bean landraces (*Khairo Ghiu Simee* and *Pahenlo Simee*) were ranked as endangered category ie being cultivated by few HHs in small area. During PSE event, total 79 individual exchange occurred where 26 farmers performed as donor farmers (Gautam et al 2017). The event was helpful on exchanging available PGR including these target two bean landraces with associated knowledge within the community and also enabled collective working environment. PSE was organized with active participation of DFS participants to minimize seed scarcity caused by 2015 earth quake.

IRD distribution: Seasonal diversity blocks, on-station seed multiplication and IRD distribution were carried under the project to increase seed availability and area coverage of farmers varieties within the site. About 100 kg of local bean seeds of the target landraces produced by on-station seed multiplication were distributed among 540 households (**Figure** 3) which is equivalent to cover approx. 5.3 Ropani (0.25 ha) of land. The process helped to improve conservation and utilization status of both beans landraces. Project coordinated with other projects' implementing organizations to test and dessiminate diversity in Kaski and Sindhuplachowk districts. Though scientifc data or records were not kept, technical staff reported that both beans have performed well in the mid hill areas and farmers were happy to receive seeds.

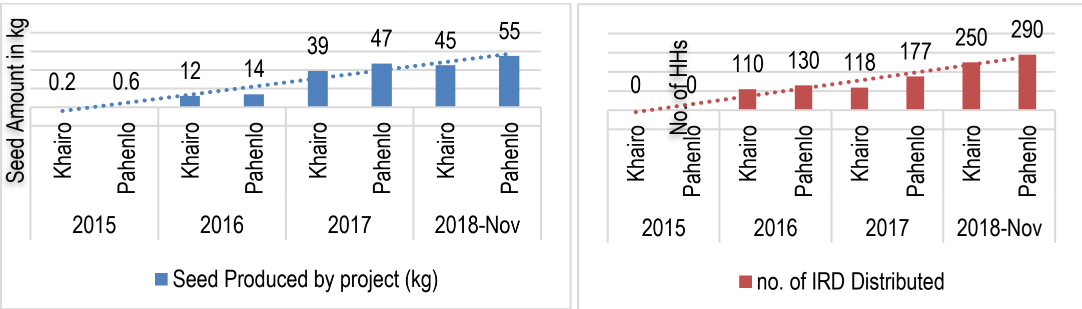

Figure 3. Year wise seed production (left) and number of seed receving HHs (right).

As these bean landraces were already preferred local varieties, farmes to farmers seed exchange and sharing contibuted significantly to reach more households within short period of time. At present, more than 80% households or over 800 farm households cultivate these beans in 5-7 meter square plot in their kitchen/home garden for vegetable purpose within the poject site. These local beans are also being promoted beyond the project site through LI-BIRD's other projects in Sindhuplanchowk and other districts, where estimated 200 farm households are already cultivating them in their kitchen gardens for household vegetable needs. Farmers are happy to restore *Khairo Ghiu Simee* and started to save their own seeds for next planting season. IRD feedback collected from random 540 households in 2017 (**Figure** 4) justifies the situation, larger percentage of farmers have saved their own seeds of *Khairo Ghiu Simee* than *Pahenlo Simee* because it was re-introduced and rare in the community. Interestingly, those HHs who didn't saved seeds have consumed all pods as green vegetable are confident enough to get seeds from their neighbours for next planting season.

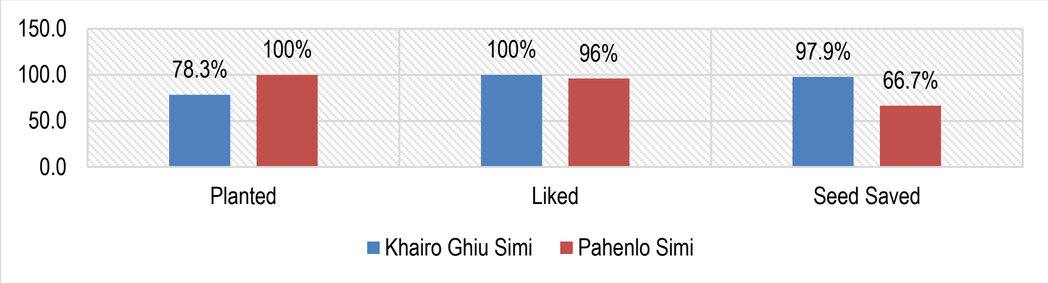

Figure 4. Farmers feedback on distributed IRD of local beans in 2018 (n=295 HHs).

Link with Community Seed Bank: From the begining of 2019, Community Seed Bank (CSB) established with project's support started to multiply targeted beans seeds in larger scale and explore market to start seed business. Project team provided technical orientation of quality seed production to the CSB members. In 2019, 100 kg of each landraces were produced and half of the seeds were traded with project support for the first time. CSB is regularly managing source seed production, multiplication and marketing of these two local beans as an iconic crop of the community. Besides production of targeted beans, CSB is continuously involved in conservation and promotion of other local crop and varieties. Linking project led initiatives to community-led CSB approach have helped to develop ownership and stewardship of all local crop diversity in the project site. Project provided opportunities to the CSB members to participate in different local to national level advocacy forum, food fairs and exhibitions to demonstrate their initiatives on local crop conservation. Jungu CSB is continuously trying to develop seed business network with public and private sectors. Jungu (Dolakha) CSB has signed a Prior Inform Concent (PIC) with a private seed company for multi-location testing and exploration of national level seed market. Sharing local plant genetic resources between farmer's institute and private seed company adopting PIC mechanism have set an example of recognizing farmer's right and developing mechanims for access and benefit sharing for local PGRs (Gauchan et al 2020).

Mainstreaming

Varietal registration: Varietal registration is the key step to link any crop variety to the formal seed system. In order to legalize and promote these two promising beans landraces, varietal registration process was carried with technical support of the project team. Variety registration proposals of both beans were developed by utilizing all available data and information generated and gathered by the project team. Developed proposals were reviewed and refined during a dedicated training workshop on farmer's variety registration facilitation in Pokhara on June 9-11 2019. As Nepal Government's National Seed Regulation (2013) has relaxed provision for registering local landraces, both proposals have been submitted under schdule "D" provision of the national seed regulation. Along with these two landaces of beans from Dolakha site, other 4 landrace registration proposals from other three LCP sites (Jumla, Humla and Lamjung) have been also submitted to the National Seed Board (NSB) for the registration process. All registered landraces will be owned by respective community organizations where line agencies will support the organizations for source seed maintenance and market promotion.

Seed business value chain development: In order to promote both varieties in commercial scale, project had supported Jungu CSB to understand, explore and develop market linkages through out the project implementation period. A seed business plan development training was organized in May 2019 in Lumle Kaski, where Jungu CSB developed a comprehensive seed business plan for 2020 focusing these two bean landraces. Business plan included collection, cleaning and packaging of the produced seeds by the CSB and then traded with other public and private institutions. Project has supported seed money to the CSB inorder to initiate seed business. Similalry, revolving fund called Community Biodiversity Management (CBM) Fund was also established so that soft loan service can be flowed to willing farmers for seed production activities which can also be used for production of bean landraces. Jungu CSB is linked with a national level private seed company for seed business and planning in partneship to do contract-based seed production .

Coordination with line agencies: Project made strong initiatives to enhance coordination and linkage with local and national line agencies and stakeholders for promoting seed value chain and mainstreaming of these bean landraces including other identified farmers' varieties. As said "together strong", from the begining of the project all concerned public agencies and local governmental bodies were well informed, involved and acknowledged during the whole process. Frequently organized joint field monitoring visits and update sharing meetings helped to enable good working environment. All concerned public agencies were well acquainted with the work and hence provided their full support on registration process. Even registration proposals have been submitted with the recommendation of local government (rural municipality) jointly by the Genebank, CDABCC[1] and farmer's institution. Similarly, local government have been providing regular financial support for the management of the Jungu CSB in Dolakha. In additional, local government has provided written commitment letter to the NSB ensuring regular financial and technical support.

Link with national research system: The Genebank played a central role in the maintainance and conservation of these two unique landraces. The seed back-up in long-term storage will be fundamental for replacing the seeds in case of varietal degeneration and farmer's variety protection in the future. The different commodity programmes like Horticulutre Research Division and National Grain legume Research of NARC will have to play a pivot role for source seed maintenance and technical back-stopping. An effort to maintain the source seeds by Horticulture Research Division, NARC was carried out by the project team.

CONCLUSIONS

Two endangered bean landraces namely *Khairo Ghiu Simee* and *Pahenlo Simee* of Jungu, Dolakha have been restored, evaluated, multiplied and mainstreamed at the local and national levels through the combined effort of local community seed bank, cooperative and the project of the implementing partners (LI-BIRD, NARC, Bioversity International). Over 1000 households are now already cultivating and using these local beans of Dolakha in Jungu and other villages of Dolakha as well other districts of Nepal. This case study has provided a process, tools and results of success story which have been effective to rescue two rare local bean landraces of Dolakha that were on the verge of extinction and promote them up to registration process at national level for commercialization and enhanced benefit sharing to farming communities. Strategic utilization of various agro-biodiversity management tools and process made possible to identify, rescue, conserve and promote two rare local crop landraces of beans by developing seed value chain and strenthening community seed bank. Collective actions built in cumulative results of participator action research and development work helped to recognize farmer's variety at national level. Similar to the beans of Dolakha, same approach can be adopted in other places to rescue, conserve and harness under utilized local plant genetic resources for conservation of agrobiodiversity and ensuring food and nutrition security of the smallholder farmers in the marginal risk-prone farming sytems.

The valuable learning in this process, is the involvement of the multidisciplinary stakeholders plays a very important role in varietal development, promotion and conservation. These kind of coordination and linkage initiatives help in promotion and mainstreaming of these identified bean landraces which ultimately help in conservation through utilisation.

REFERENCES

Bezançon, G, JL Pham, M Deu, Y Vigouroux, F Sagnard, C Mariac, I Kapran, A Mamadou, B Gérard, J Ndjeunga and J Chantereau. 2009. Changes in the diversity and geographic distribution of cultivated millet (*Pennisetum glaucum* (L.) R. Br.) and sorghum (*Sorghum bicolor* (L.) Moench) varieties in niger between 1976 and 2003. Genet. Resource Crop Ev. **56:**223-236.

Gauchan, D, BK Joshi, B Bhandari, DS Shrestha, S Shrestha and D Jarvis. 2020. Community-based mechanisms for promoting access and benefit sharing. **In**: Good Practices for Agrobiodiversity Management (Joshi BK, D Gauchan, B Bhandari and D Jarvis, eds.) . NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gauchan D, BK Joshi, KH Ghimire, K Paudel, S Sapkota, S Sharma, DMS Dangol, S Khatiwada, S Gautam and S Sthapit. 2018. Rebuilding local seed system and safeguarding conservation of agrobiodiversity in the aftermath of Nepal 2015 earthquake. The Journal of Agriculture & Environment **19**:131-140.

Gautam S, S Sthapit, D Gauchan, B Dhakal, N Pudasaini and R Yadav. 2017. Participatory seed exchanges restores farmers' access to diverse seeds in the aftermath of the 2015 earthquake in Nepal. **In:** Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal (BK Joshi and D Gauchan, eds). Proceedings of Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, LIBIRD, BI and Crop Trust.

[1] Centre for Crop Development and Agro-Biodiversity Conservation Center (CCDABC) is newly formalized governmental entity under Department of Agriculture mandated to work on conservation and promotion of local crops diversity of Nepal.

Gurung R, R Dhakal, N Pudasaini, PB Paneru, S Pant, AR Adhikari, S Gautam, RK Yadav, KH Ghimire, BK Joshi, D Gauchan, S Shrestha and DIJarvis. 2019. Catalogue of Traditional Mountain Crop Landraces in Nepal. LI-BIRD, Pokhara, NARC, Kathmandu and Bioversity International, Nepal (www.himalayancrops.org).

Himalayan Crops Website (http://himalayancrops.org/2016/06/03/local-crop-diversity-fair-in-jugu-dolakha-a-move-towards-normal-life-in-the-aftermath-of-devastating-earthquake/)

Jarvis DI, V Zoes, D Nares and T Hodgkin. 2004. On-farm management of crop genetic diversity and the convention on biological diversity's programme of work on agricultural biodiversity. Plant Genet. Resource. News. **138:**5-17.

Jarvis D and T, Hodgkin. 2008. The maintenance of crop genetic diversity on farm: Supporting the Convention on Biological Diversity's Programme of Work on agricultural biodiversity. The Value of Biodiversity to Food and Agriculture **9**(1&2):23-28.

Jarvis D, T Hodgkin, BR Sthapit, C Fadda and I Lopez-Noriega. 2010. A heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. Critical Reviews in Plant Sciences **30**(1-2):1-49.

Joshi BK, D Gauchan, B Bhandari and D Jarvis, eds. 2020. Good Practices for Agrobiodiversity Management. NAGRC, LI-BIRD and Bioversity International, Kathmandu, Nepal.

Joshi, BK, AK Acharya, D Gauchan, MR Bhatta and MP Upadhyay. 2017. Agro-biodiversity status and conservation options and methods. **In**: Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Proceedings of 2nd National Workshop, 22-23 May 2017 Dhulikhel: NAGRC, FDD, DoA and MoAD, Nepal.

Jungu VDC Profile. 2009. Village Profile and Situation Analysis. Village Development Committee Office, Jungu, Dolakha.

Linkha B and N Pudasaini. 2019. Promotion of native crop varieties: *Khaio Ghiu Simi* as an example of Dolakha. **In**: Stories of Changes (KH Gmimire, N Pudasaini and D Gauchan eds). Local Crop Project (UNEP GEF), LI-BIRD, NARC and Bioversity International, Nepal.

Pudasaini N, SR Sthapit, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: I. Jungu, Dolakha. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.

Sthapit BR, PK Shrestha and MP Upadhyay, eds. 2006. Good Practices: On-farm Management of Agricultural Biodiversity in Nepal. NARC, LI-BIRD, International Plant Genetic Resources Institute and IDRC, Kathmandu, Nepal.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

On-farm Diversity and Consumption Choices of Traditional Crops in the Mountains of Nepal

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ABSTRACT

Management of production diversity and farmers' consumption choices of traditional crops play an important role in household food and nutrition security of mountain communities, where production, access and availability of major food stapes (rice, wheat, maize) and conventional vegetables (leafy green and others) are limited due to remoteness, marginal risk-prone environments and poverty. This study analyzed the household, agroecological and socioeconomic factors influencing management of on-farm diversity and consumption choices of the households. The study covers three selected traditional crops of the mountain agroecosystems, namely, amaranth, bean and buckwheat that are consumed as both food staples and vegetables in the rural mountains. It used data from sample surveys of 328 households from four representative mountain agroecosystems of Humla, Jumla, Lamjung and Dolakha districts in 2015. The sample survey was supplemented with participatory rural appraisals, field monitoring visits and consultation meeting with key stakeholders. Poison and Probit regression models were used to assess factors driving household's decision to maintain varietal diversity and consume traditional crops as major food staples and vegetables. Factors influencing on-farm production diversity and consumption choices varied with the crops. For on-farm diversity, major influencing factors are farmers' age, farm size, crop area, agroecology, number of female members in the households, and market distance. However, for factors influencing farmers' decision to consume green leafy vegetables were farm size, agroecological factor, number of female members and households' members working outside the villages. Findings imply that future research and development interventions need to focus on diversity-rich solutions and technologies tailored to specific crops and socioeconomic and farm-agroecological conditions of the households to promote on-farm diversity and consumption choices of the farm households for enhancing household food and nutrition security.

Keywords: Agriculture-nutrition linkage, mountain agroecosystem, production diversity, underutilized crops

INTRODUCTION

The mountain region of Nepal has high incidence of poverty, food insecurity and malnutrition (NPC 2016). Data show that the rate of children stunting under 5 years is severe in the mountains (46.8%) as compared to Tarai (36.7%) and hill (32.3%) with the highest rate of stunting (54.5%) in the western mountains of Karnali province (NDHS 2016). The households in the mountain region are also more vulnerable to food insecurity and chronic malnutrition due to low per capita food production, higher food prices, poor connectivity and limited market availability (Gauchan 2019). The smallholder farmers in the mountain region of Nepal depend on globally important biodiversity of traditional food crops for their local food and nutrition security. These include intraspecific diversity of buckwheat, barley, naked barley, different species of millets (finger millet, proso millet, and foxtail millet), amaranth and bean that have unique traits of stress tolerance adapted to harsh risk prone marginal environments (UNEP GEF 2013). In the risk prone mountains, presently production, access and availability of major food staples (rice, wheat) and conventional vegetables (leafy green and others) used in diet are limited due to remoteness, marginal risk-prone environments and poverty.

Among the several traditional underutilized crops, amaranth, bean and buckwheat are important ones as they are cultivated both for staple food and green nutritious vegetables, providing food and nutrition security to marginalized people in the mountains (Gurung et al 2016, Pudasaini et al 2016, Palikhey et al 2017, Parajuli et al 2017). These traditional crops are cultivated in the mountain regions over millennia by farmers and hence have helped to meet the food and nutrition security of the marginalized communities in the face of changing climate. These crops are rich in micronutrients (calcium, iron) with high dietary fibers, rare amino acids, antioxidants and vitamins and contain higher protein as compared to major food staples such as rice, and wheat (DFTQC 2012, Joshi et al 2020). Hence, they are considered Himalayan Superfoods (www.himalayancrops.org), crops for the future and also future smart foods (Li and Siddique 2018, Joshi et al 2019; Gauchan et al 2019). Even though, these traditional mountain crops are considered minor crops at the national level, they happen to be the principal crops of mountain region of Nepal (Gauchan et al 2019). For instance, buckwheat is a number one crop in Mustang and Manang and second most important ones in Dolpa district (MoAD 2016, Joshi et al 2014). Amaranth is important food and cash crops in the far western mountain districts particularly in Bhajang, Bajura and Doti.

Despite the importance of these crops for food and nutrition security, we have limited information about the factors influencing on-farm diversity and farmers' consumption choices of nutrient dense traditional crops among mountain communities. Previous studies of rice in the middle mountains have shown that there are various socioeconomic, market and agroecological determinants of farmers' maintenance of diversity in households (Gauchan et al 2005). Similar to this, in this study, we aim to assess various socioeconomic, agroecological and market factors influencing on-farm production diversity and household consumption choices for the selected nutrient dense traditional crops (buckwheat, bean and amaranth) in the mountains of Nepal.

RESEARCH METHODS

This study is focused on three important traditional crops namely buckwheat, bean and amaranth that are cultivated and used for both food staples (grains) and vegetables. The study consists of statistically representative sample survey of 328 randomly selected farm households from four representative districts of high altitude regions (1500-3000 msl) of the mountains in Nepal. The survey was carried out using proportionate random sampling of 72-90 households from one selected representative village development committee (VDC) of Humla, Jumla, Lamjung and Dolakha districts representing western, central and eastern mountains. The survey was carried out using specifically designed questionnaire on household socioeconomic features, land use, tenancy, market factors, crop varieties grown, seed sources, food sufficiency, production diversity and household consumption of vegetables. The information was supplemented from participatory rural appraisals, field monitoring visits, stakeholder consultation and literature review on mountain production systems. Nutrition security is assessed from own production, household sufficiency and consumption of green leafy and other vegetables and pulse production. Poisson regression model was used to assess factors influencing household maintenance of on-farm diversity, while Probit regression model was used to analyse farm household's decision to consume green leafy vegetables of these traditional crops (amaranths, buckwheat, bean). Data was analyzed using Microsoft Excel, Statistical Package for the Social Sciences (SPSS) 16 for descriptive analysis and STATA (10.0) for econometric analysis.

Analytical models

Poisson regression model

Poisson regression model was used for factors influencing maintenance of traditional crop diversity. The preponderance of small values and the clearly discrete nature of the dependent variable (variety count data) with non-negative integer suggests the use of a Poisson maximum likelihood regression (Greene 2000). The log-linear regression in the Poisson model naturally accounts for the non-negativity of the Poisson distribution dependent variable (Winkelmann and Zimmermann 1995). The count data specification for richness measure was utilised because of the way it gives the model flexibility to explain cultivar diversity within a crop. The Poisson regression model is given as:

$$D_i = \beta_o + \beta_1 X_H + \beta_2 X_F + \beta_3 X_M + \boldsymbol{\varepsilon}$$

Where D_i = measure of crop diversity-richness (count of crop varieties) of household i

X_H = socioeconomic characteristics (age, education, family size, farm size, gender, female members, members working outside village, share cropping)

X_F = agroecological characteristics (located in western or eastern mountains)

X_M = market characteristics (total distance to market)

β = coefficient

ε = disturbance term

Probit regression model

The Probit regression model was used here to study the household specific socioeconomic and institutional factors influencing farmers' choice of consumption of green leafy vegetables from amaranth and buckwheat. The dependent variable in the Probit model is the dichotomous variable that takes value 1 for farmers' choices of consumption and zero for the non-consumption (Maddala 1983). The model was specified as:

$$Y^* = X\beta + u \qquad Y = \begin{cases} 1 & if \quad Y^* > 0 \\ 0 & otherwise \end{cases}$$

such that the residual, $u \sim IN(0, \sigma^2)$

where Y* is the unobserved underlying stimulus index of consumption of green vegetables from amaranth and buckwheat and 'Y' is the (n x 1) observable dependent variable which is equal to 1 if the farm household choose to consume and 0 otherwise; β is the (k x 1) vector of unknown parameters; and X is the (n x k) vector of exogenous or predetermined variables such as socioeconomic, agroecological and market variables.

FINDINGS AND DISCUSSION

Household socio-demography

The socio-demographic information of the sample households is presented in **Table** 1. Sample households are dominated by middle age farmers (44 years) with average family size of 6 persons and average farm size of 0.5 ha (10 ropani). This indicates the predominance of smallholder farmers with smaller farm size as compared to national average of 0.68 ha. Over half of the sample households have nuclear families and about one-fifth of them are female decision makers. About 50% of the sample households fall under disadvantaged groups (Dalit and Janajati), which is highest in Lamjung (96%).

Table 1. Household socio-demographic information in study sites in 2014 (n=328)

Socio-Demography	Humla (n=72)	Jumla (n=83)	Lamjung (n=83)	Dolakha (n=90)	All (n =328)
Age of the respondents (years)	37.9	39.5	51.9	47.0	44.0
Farm size (ropani)*	4.4	8.00	18.2	10.4	10.4
Family size (n)	5.3	6.0	6.4	5.8	5.9
Nuclear households (%)	68	61	42	60	58
Female members in the households (%)	28	46	37	59	46
Female decision makers (%)	6	24	28	38	23
Disadvantaged groups (Dalit & Janjati) (%)	15	45	96	31	48

**: One Ropani = 500 sq meter.*

Cereals, pulse and vegetable sufficiency

Cereals (rice, wheat, maize, millet and buckwheat), pulse (bean and other grain legumes) and vegetables (both leafy and others) are important foods consumed by the households in Nepal. Farmers in high mountains of Humla, Jumla, Lamjung and Dolakha are consuming amaranth, buckwheat and bean at the household level both as staple food grains and green vegetables. The green leafy part of young plants of amaranth and buckwheat and green pods of bean are mainly consumed as vegetables. The average food staple, pulse and vegetable availability and sufficiency period from their own production from these crops is less than 4 months in Humla and Jumla and 5-6 months in Lamjung and Dolakha (**Figure** 1). The pulse (bean) sufficiency was relatively higher in Jumla for about 6 months. The level of cereals sufficiency was relatively higher in Lamjung and Dolakha and vegetables in Jumla.

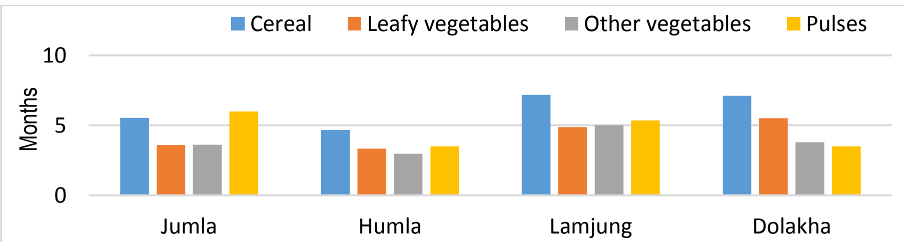

Figure 1. Status of household food and vegetable self-sufficiency (months) in study sites in 2014-2015.

On-farm diversity of traditional crops

On-farm diversity of traditional mountain crops (amaranth, bean and buckwheat) is measured in terms of (i) proportion of farm households cultivating these crops, (ii) farm area allocation to these crops and (iii) number of varieties (richness) grown by farmers at the households and community levels. These are briefly outlined below.

Proportion of households growing crops

Amaranth, bean and buckwheat are grown by farm households in all the study sites with high proportion for bean, while fairly modest for amaranth and lower proportion for buckwheat (Figure 2). Among these three crops, bean is grown by large proportion of the households in Jumla (98%), Humla (88%) and Dolakha (80%) while about 40% of the households in Lamjung. Amaranth is grown by large proportion of households in Humla (80%), but only one-third of the households in Jumla and very low proportion of the households in Dolakha and Lamjung. Buckwheat is grown by 60% of the households in Humla but very low proportion of the households in Jumla, Dolakha and Lamjung.

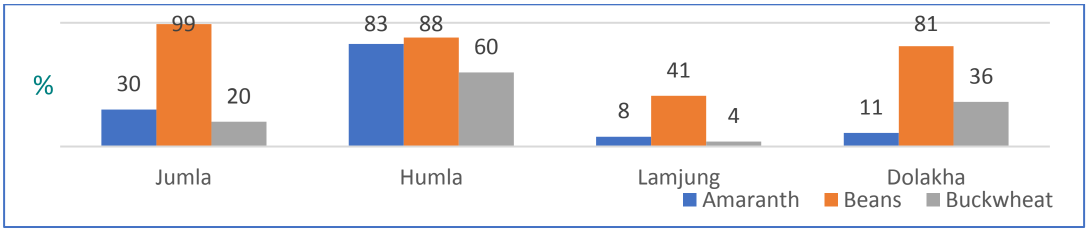

Figure 2. Percent households growing traditional mountain crops in study sites.

Farm area allocation to traditional mountain crops

Since farm households in mountain areas have small farm sizes (<0.5 ha), they grow traditional crops in relatively smaller area (Table 2) by mixing different landraces and crop species. The area share of different traditional crops to total cultivated farm area in the study sites ranges from less than 1% for amaranth to 3 % for bean and 10.5 % for buckwheat. These crops are grown in small area in the fields.).

Table 2. Average area allocations (Ropani) to selected traditional crops in 2014-15

Crop	Jumla	Humla	Lamjung	Dolakha	Overall Average	Area share (%)*
Amaranth	0.027	0.12	-	-	0.06	0.57
Bean	1.88	0.48	0.38	0.026	0.35	3.4
Buckwheat	0.69	0.88	-	2.46	1.10	10.5
Farm size	8.06	4.29	18.22	10.44	10.46	100

**, Area share includes percent share of specific crop area to total crop cultivated area by farmers.*

Amaranth is grown in Jumla and Humla and buckwheat in Jumla, Humla and Dolakha, while bean is grown in all the sites from far western to eastern part (Gurung et al 2017, Pudasaini et al 2017, Palikhey et al 2018, Parajuli et al 2018).

Diversity of crop varieties at community level

A high intra-specific diversity of selected traditional crops was found to be maintained at community level in all four mountain agroecosystems. The varietal richness or a number of varieties grown by farm households, an indicator of crop diversity was found highest for bean in Jumla and Dolakha and low for amaranth and buckwheat in all the study sites (Figure 3).

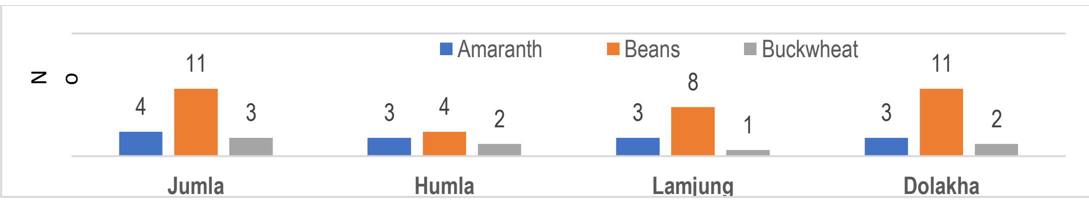

Figure 3. Crop varietal richness of traditional crops at community level.

Factors influencing on-farm crop diversity

A Poisson regression model was used to assess various socioeconomic, agroecological and market factors influencing farmers' choices to cultivate and maintain on-farm varietal diversity of amaranth, buckwheat and bean. Factors influencing maintenance of on-farm cultivar diversity vary with crop types (**Table** 3). Major factors influencing are mostly related with farmers' age, number of female members in the households, farm size, crop area, agroecology and market distance depending upon crop types. Presence of female members was important for buckwheat, while farm size was important for bean diversity maintenance. On-farm diversity is also more related with consumption choices for amaranth green leaves showing linkage between diversity and nutrition. Agroecology (locations in western vs eastern mountains) and market distance are important for maintenance of cultivar diversity in amaranth and bean, while crop area allocation was important for all crops.

Table 3. Poisson regression results: amaranth, buckwheat and bean in the mountains of Nepal

Household characteristics	Amaranth	Buckwheat	Bean
Age (years)	0.469**	0.000 ns	-0.005**
Gender (Male/Female)	0.212 ns	0.193	0.015 ns
Household size	0.029 ns	0.069 ns	-0.007 ns
Female members (number)	0.045 ns	0.332**	-0.007 ns
Farm size (ropani)	-0.011 ns	-0.449 ns	0.020 **
Crop area (ropani)	1.202***	1.022 ***	0.257***
Work outside the village (yes/no)	0.501 ns	0.005 ns	-0.172
Consume green parts (yes/no)	0.469 *	0.775	-
Training in NUS crops (yes/no)	-0.189 ns	-0.257	-0.193 ns
Agroecology (western vs eastern)	2.460***	0.350*	-0.163 ns
Market distance (km)	0.064 **	0.073 **	-0.006 ns
Constant	-5.421***	-2.397 ns	1.218 **
Number of observations	323	152	323
Likelihood ratio [LR chi2 (11)]	171.51 ***	50.13***	45.90***

****, ** and * significant at p<0.01; 0.05 and 0.1, respectively.*

Factors influencing consumption choices

Amaranth and buckwheat green leaves are important vegetables in the high mountain regions where farmers have limited access of other vegetable sources due to harsh climatic conditions, poor connectivity and lack of market access. A Probit regression model was used to identify various socioeconomic, agroecological and market factors influencing farmers' choices to consume green leafy vegetables of amaranth and buckwheat. The model results showed that factors influencing farmers' decision to consume green leafy vegetables for both amaranth and buckwheat were farm size and agroecological factors (**Table** 4).

Table 4. Probit regression results of amaranth and buckwheat in the mountains of Nepal

Household characteristics	Amaranth	Buckwheat
Age (years)	0.0029 ns	-0.001 ns
Gender (Male/Female)	-0.011 ns	-0,219 ns
Household size	-0,0001 ns	-0.048 ns
Female members (number)	0.110 ns	0.317 ***
Farm size (ropani)	0.019 **	0.018 *
Share cropping (yes/no)	0.296 *	0.024 ns
Work outside the village (yes/no)	0.069 ns	0.111*
Vegetable sufficiency (month)	0,032 ns	0.111
Agroecology (western vs eastern)	0.487 *	1.27 ***
Market distance (km)	0.016 ns	0.024 ns
Constant	-1.2154 ns	-0.360 ns
Number of observations	301	301
Likelihood ratio [LR chi2 (10)]	20.44 **	60.91***

****, ** and * significant at p<0.01; 0.05 and 0.1, respectively.*

However, for some other factors, farmers' decision varied depending upon crop types. For instance, share-croppers are more likely to choose to consume green leaves of amaranth as vegetables, while households with more female members and household members working outside the native village are more likely to consume green leaves of buckwheat as vegetables. The extent of significance of agroecological factor was more in buckwheat, while for farm size it was for amaranth.

CONCLUSIONS AND WAY FORWARD

Management of on-farm diversity and consumption choices of traditional crops play important role in household food and nutrition security of mountain communities, where production, access and availability of major food stapes (rice, wheat, maize) and conventional vegetables (leafy green and others) are limited due to remoteness, marginal risk-prone environments and poverty. Factors influencing on-farm diversity of the three traditional nutrient dense crops (amaranth, buckwheat and bean) were varied by agro-ecological, farming system and socioeconomic conditions of the mountain locations. Factors influencing on-farm production diversity and consumption choices varied with the crops. For on-farm diversity, major factors influencing are farmers' age, farm size, crop area, agroecology, number of female members in the households, and market distance. However, for factors influencing farmers' decision to consume green leafy vegetables were farm size, agroecological factor, number of female members and number of household members working outside the native villages. Farm size and agroecology were most significant factors influencing on-farm diversity and consumption choices, while market factor was only important for maintaining on-farm diversity but not for consumption choices. This indicates that larger farmers and farm households located in far western high mountains of Karnali (Jumla and Humla) are more likely to maintain on-farm diversity and for household consumption for green leafy vegetables.

Access to market has not much effect on consumption choices of green leafy vegetables of amaranth and buckwheat as they are traditional subsistence crops. Future research and development interventions, therefore, need to focus on diversity-rich solutions and technologies tailored to specific crops, socioeconomic and farm-agroecological conditions of the mountain households to enhance household food security and management of crop biodiversity. The findings imply that, there is a need to focus on the cultivation and consumption of traditional crops (amaranth, buckwheat and bean) for food and nutrition security especially in western mountain regions particularly in Karnali province and to relatively larger farm size. This will require an increased need of developing and promoting diverse set and choices of varieties of traditional crops with different maturity and planting seasons to increase diversity-rich production of these crops and promote year-round consumption of these crops for enhanced nutrition of rural remote households. Such strategy will support not only for maintaining greater local crop biodiversity but also improve nutrition and health of farm households and promote resilience of smallholder farming systems to unpredictable environmental changes in Nepal Himalayas.

REFERENCES

DFTQC. 2012. Food Composition Table for Nepal. Department of Food Technology and Quality Control (DFTQC), National Nutrition Program, Ministry of Agriculture Development, Government of Nepal, Kathmandu.

Gauchan. 2019. Exploiting Biodiversity of Traditional Crops for Mainstreaming Nutrition Sensitive Agriculture in Nepal. NAPA Research and Policy Brief, RPB #5, 2019. Association of Nepalese Agricultural Professionals of America (NAPA). www.napaamericas.org

Gauchan D, B Bhandari, R Gurung, BK Joshi, and D Jarvis. 2019. Value chain development of underutilized food crops for nutrition sensitive agriculture in the mountains of Nepal. **In**: Proceeding 5th International Agricultural Marketing Conference, Kathmandu, June 4-5, 2018. Nepal Agricultural Economic Society (NAES), Ministry of Agriculture and Livestock Development (MoALD), FAO, KISSAN-2, USAID, Nepal.

Gauchan D, M Smale, N Maxted, M Cole, BR Sthapit, D Jarvis, and MP Upadhyay. 2005. Socioeconomic and agroecological determinants of conserving diversity on-farm: The case of rice genetic resources in Nepal. Agric. Res. J. **6**:89-98.

Greene WH. 2000. Econometric Analysis. Fourth Edition. Prentice Hall. USA.

Gurung R, SR Sthapit, D Gauchan, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: Ghanpokhara, Lamjung. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Joshi BK, ML Vaidya, HK Upreti, DR Sharma, CB Rana, PM Mahat, SR Gupta and S Bista. 2014. Rice and buckwheat genetic resources in Karnali zone. Agriculture Development Journal **10**:1-22.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. **In**: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Joshi BK, R Shrestha, D Gauchan and A Shrestha. 2019. Neglected, underutilized, and future smart crop species in Nepal, Journal of Crop Improvement. **DOI**: 10.1080/15427528.2019.1703230

Li X and KHM Siddique. 2018. Future Smart Food. Rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia, Bangkok.

NDHS. 2016. Nepal Demographic Health Survey (NDHS). Ministry of Health and Population. Kathmandu, Nepal:

NPC. 2016. Nepal and Millennium Development Goals: Final Status Report: 2000-2015. National Planning Commission (NPC), Kathmandu, Nepal:

Palikhey, E., SR Sthapit, S Gautam, D Gauchan, B Bhandari, BK Joshi, and BR Sthapit. 2017. Baseline Survey Report: Hanku, Jumla. Integrating Traditional Crop Genetic Diversity into Technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.Parajuli, A, A Subedi, AR, Adhikari, SR Sthapit, BK Joshi, D Gauchan, B Bhandari and BR Sthapit. 2018. Baseline Survey Report: Chhipra, Humla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Parajuli A, A Subedi, AR Adhikari, SR Sthapit, BK Joshi, D Gauchan, B Bhandari and BR Sthapit. 2017. Baseline Survey Report: Chhipra, Humla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Pudasaini, N, SR, Sthapit, D Gauchan, B Bhandari, BK, Joshi and BR, Sthapit. 2016. Baseline Survey Report: Jungu, Dolakha. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Nepal: LI-BIRD, NARC and Bioversity International.

Maddala GS. 1983. Limited Dependent and Qualitative Variables in Econometrics. Econometric, Society Monographs, vol. 3. Cambridge University Press, Cambridge.

MoAD. 2016. Statistical Information on Nepalese Agriculture. Ministry of Agriculture Development (MoAD), Government of Nepal. Singh Durbar, Kathmandu, Nepal.

UNEP GEF. 2013. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to buffer against Unpredictable Environmental Change in Nepal Himalayas. Project Document, United Nation Environment Program (UNEP), Global Environment Facility (GEF) and Bioversity International, Kathmandu, Nepal.

Winkelmann R and KF Zimmerman. 1995. Recent developments in count data modelling: Theory and application. Journal of Economic Surveys **9**:1-24.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

The Fate of Mountain Farming System Relies on Women Farmers: A Case of Dolakha, Nepal

Niranjan Pudasaini, Devendra Gauchan, Bharat Bhandari and Bishnu Dhakal

ABSTRACT

Traditional farming systems of the Nepalese Himalayas consists of pronounced agricultural biodiversity, rich indigenous knowledge and socio-cultural practices. Contemporary issues like changing climate, out-migration and adoption of modern lifestyles have intervened the traditional socio-cultural settings and the farming system. The aim of this study is to assess changes in gender specific participation and the roles of managing traditional farming systems as consequences of out-migration of man and youth from farm family in the mountains. Household surveys, focused group discussions and key informant interviews were conducted in Jungu village of Dolakha district of central mountains in Nepal. In the study site, 92% of the households have at least one migrant family member for a short period of one month to more than 3 months. Substantial involvement of women in farming systems coupled with a large percentage of man out-migration has by default or compulsion placed women farmers in the frontline of traditional farming system in the mountains. Increased multiple responsibility and associated workloads in part of women farmers have contributed reduction in cultivation area and crop varietal richness at household level. On the other hand, despite being a patriarchal society there is a significant shift in part of women in household and farm level decisions leading to feminization. Therefore, rural women farmers are the key determinants of continuing traditional farming system and conserving local agricultural biodiversity in the study area. However, women farmers' role in management of mountain farming system and conservation of agrobiodiversity is less visible and not adequately recognised by formal sector agencies in Nepal. As a result, women farmers are deprived of accessing adequate level of information, skill development opportunities and receive other support services in engaging farming activities and increase productivity. Any interventions aiming to improve rural farming systems, conserve and utilize local agro-biodiversity should thus be women farmer centric for effective results and sustainability. Hence, it is essential to have a platform of knowledge sharing and leadership enhancement opportunities for women at the community level.

Keywords: Agro-biodiversity conservation, gender roles, migration, mountains, traditional farming system

INTRODUCTION

Nepal is globally renowned for agro-ecological and biological diversity accompanied with rich socio-cultural diversity. Rich genetic diversity, indigenous knowledge and the socio-economic setting has allowed people to sustain their agrarian livelihood in harsh, complex and risk-prone mountain environments particularly in mountain areas of the country. Traditional farming systems with rich indigenous knowledge and culture are the key for mountain food and nutritional security (Gauchan 2008). Nepal is an agriculture-based economy, with about 74% of the population dependent on agriculture and where 81% of the population is rural (CBS 2013). Contemporary challenges like biodiversity loss, climate change and globalization have pronouncedly impacted rural socio-cultural and traditional farming systems of the rural mountain areas of Nepal. In Nepalese context, socio-economic influences of any external driving force vary with ethnicity, caste and gender. Livelihood strategy, resource utilization and management vary depending on ethnic composition and their traditional culture norms.

Traditionally gender specific roles on farming matters and household level decision making processes are highly male-dominated in the patriarchal socio-culture of Nepal which has immense implications on traditional farming matters and resource management (Chant and Sweetman 2012, Honsberger 2015, IFAD 2000). Most of the agricultural tools and technologies either traditional or modern are developed based on knowledge who operates them as shaped and influenced by the social norms and convenience (Lal 2009). Women family members are forced to work daily at household and farms as they are increasingly managing families and mostly confined at homes. Studies from Nepal and outside show that women involvement is high in high drudgery ranked works such as harvesting, weeding, threshing and post-harvest processing while men prefer to engage in activities like marketing, tillage operation, manuring and fertilizing the crops (Mrunalini and Snehalatha 2010, Thakur et al 2001).

Culturally, men have greater role for household level decision making as well as having control over resource ownership and mobilization as compared to women. As male members get more opportunities for education, access to information and exposure, their attraction towards off-farm work for income generation has been increased in recent time (Honsberger 2015). It has therefore become common practice for male family member to migrate overseas and/or to urban areas for off-farm employment which is more economically attractive than traditional subsistence agriculture. This kind of trend has gradually shifting priorities of rural families to look for off-farm opportunities and relying more and more on labor migration to earn remittance as a major livelihood strategy to fulfill their basic requirements and meet family aspirations (Tamang et al 2014). According to Gartaula et al (2010), between the older and younger generation, notably the latter (including women and youth) wants to move out of agriculture. National data shows 55.8% of households have at least one member outside the household are receiving remittance. The data also showed that the share of remittance in the household income was 30.9%, where, nine out of ten people who left the country recently were men (CBS 2011).

Out migration has prompted distinctive situations in rural areas impacting on traditional farming systems which is based on natural, genetic and socio-cultural diversity and associated knowledge base (Gartaula et al 2010, Maharjan 2010). However, it has been realized crucial to assess and take appropriate measures to address gender gaps that would contribute significantly to agricultural and societal development (World Bank 2009, FAO 2011). The dynamics of out-migration and the changing context and needs of the rural areas has to be assessed in order to develop any projects and programs aiming to strengthen agriculture sector building and rural farming systems. In the context of implementing Local Crop Project, this paper examines the changes in gender roles, household decision making and their actual and potential implications on traditional crops due to out-migration of family members in Jungu village (Gaurishankar Rural Municipality 1 & 2) of Dolakha district in the central mountains of Nepal.

Conceptual framework of the study

The study has considered three driving forces of out-migration; climate change induced stresses, opportunities created by the globalization and the prevailing unemployment at local level (**Figure** 1). Push factors (low agricultural productivity and increase in risks due to climate change-induced stresses, poverty and lack of employment) in origin and pull factors (better income and employment opportunities, access to better modern amenities and social safety) in destination influence migration decisions. Similarly, poor social welfare provisions, caste-based social discrimination and resource conflicts are some of other pushing factors of rural mountain areas (King 2014). Both pulling and pushing factors can be permanent or temporary type as well as caused by human-induced or nature-caused.

Research indicates that climatic zones in Nepal have shifted (eg increases in monsoon precipitation and more erratic rainfall) resulting to experiencing increasingly unfavorable conditions for agricultural activities (Malla 2008). There is decreasing number of rainy days, but higher intensity rainfall events are increasing (Baidya et al 2008). IPCC (2007) have described potential economic consequences including productivity changes in agriculture (especially in rain-fed agricultural system) and other climate sensitive sectors. Increasing climatic stresses have led farmers to search off-farm income options to sustain their livelihood, hence changing climate is acting as a push factor for out-migration. Changes in the rural society due to improvement in market access, globalization and modernization has been visible in economic, cultural and political sectors. ADB (2013) argued that weak performance of agricultural sector, high population growth and unstable political situation prompted many of the most productive members of rural households to migrate internally or internationally in recent years. As traditional farming systems are labor intensive and economically less beneficial, the youth are losing interest and do not consider agriculture as an occupation for long-term career development. With increasing educational access and qualification, youth are more attracted towards off-farm opportunities but, lack of off-farm opportunities locally is a compelling factor for out-migration (Gautam 1999).

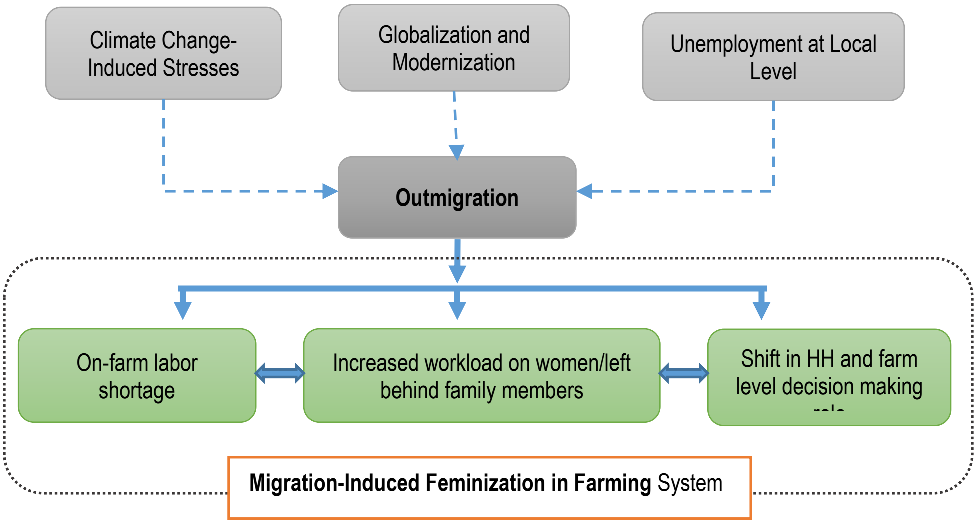

Figure 1. Conceptual framework for migration-induced feminization in the mountains of Nepal.

As outlined in **Figure** 1, outmigration has been the major challenge for Nepal's hills and mountain altering socio-cultural lifestyle and farming systems and shift in gender roles and responsibility. In a way, it has opened up opportunities for women expose and take leaderships in the family and society. This framework hypothesizes that, migration has caused a shift in gender roles and responsibilities in traditional farming system ie feminization in rural agriculture. The research aspires to assess the implications of out-migration in traditional farming systems considering labor availability, gender-wise involvement and decision-making roles.

MATERIALS AND METHODS

The study was conducted in Gaurishankar Rural Municipality (Ward 1 & 2), former Jungu Village Development Committee (VDC) of Dolakha a mountainous district of the central development region in Nepal (now Bagmati Province). It is the site of the Local Crop Project jointly implemented by NAGRC, LI-BIRD and Bioversity international under the funding support of UNEP-GEF. Primary information were collected using Participatory Rural Appraisal (PRA) tools and household survey in 2015. Secondary information from related publications, reports and articles were also accessed and used. Quantitative data were collected through a semi-structured questionnaire survey of farm households, adopting probability proportion to size sampling technique. The household name list prepared by the research project gave a household count of 991 in total, which was used as the basis for sampling and conducting the survey in January 2015. In total, 991 residing households were listed and a sample size of 88 was calculated using a sample size estimation formula. This calculated sample size has a 95% confidence level within the 10% margin of error. A total of 90 households were sampled[2] using numbers randomly generated from Windows MS-Excel 2013.

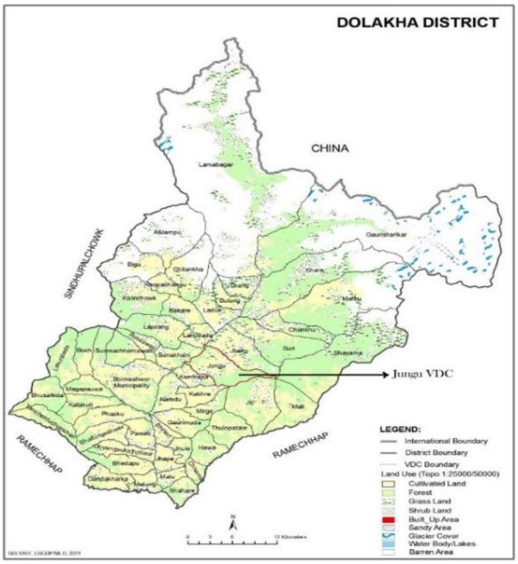

Figure 2. Map of Dolakha district showing the Jungu VDC.

[2] *Rounding up of the values from probability proportion to size technique leads to increase two HHs in total and hence 90 HHs were surveyed which is more than calculated sample size*

Qualitative data were collected thorough Focus Group Discussions (FGD), Key Informant Survey (KIS), participant observation and community transect walks. During FGD, perceived change was ranked (1=low, 2=medium and 3=high) in a participatory way and presented in spider web graph. Study has considered more than three months' migration or out residency from household as an influential[3] migration and the data are interpreted and tested accordingly for decision making roles. Primary data obtained from household survey were analysed using Ms-Excel 2013 and SPSS 16. Explorative statistical analysis (mean, frequency, standard deviation and standard error) and Chi-square test were calculated. Results were interpreted and cross validated with supporting literatures to draw relevant conclusions.

About agro-ecology, population and farming systems of the study sites

Dolakha is a mountainous district which lies under the Bagmati Province of Nepal. Jungu lies in the north-eastern region of the district in Gaurishankar Rural Municipality (Ward no. 1 & 2). The Jungu village extends from 27°50' to 27°43' North, and 86°8' to 86°15' East, and has an altitude range of 950 to 3000 masl. The village covers an area of 33 km^2, where 60% of the land area is under forest with 40% cultivable land. The land topography is steep where terrace farming is common system in the undulating landscape ranging from 950 masl to 3000 masl.

RESULTS AND DISCUSSION

The farming system is mainly characterised by crop-livestock-agroforestry system, within which diverse cropping patterns are prevalent. Rice-based cropping pattern in the lower altitude (950-1500 masl), maize and millet-based cropping pattern in the mid altitude (1500-2000 masl) upland areas and maize/potato and livestock- based high land farming system in the higher altitude (2000-3000 masl) areas are commonly practiced. Among cultivated major cereals, rice and finger millet are the most common while barley and buckwheat are grown in smaller area as they are associated with cultural aspects of the community. The existing farming system is traditional with labor intensive production and processing systems using manual labor and traditional technologies (Pudasaini et al 2016). Agriculture is the primary source of occupation for the majority (56%) of households, followed by various forms of non-agriculture professions including labor work. Foreign remittance is major source for 11% households. In-country service, remittance, business, agricultural labor (work for cash in others' farms), and the collection of medicinal and aromatic plants (MAPs) are the other major sources of income identified. Farmers are mainly smallholders with the average landholding size of 0.42 ha (where 0.21 ha is cultivated land), which is lower than the national average value of 0.68 ha (CSB, 2013).

Socio-economic characteristics

Out of 90 interviewed respondents, 41% of farmers were men and 59% were women. In Jungu, Brahmin/Chhetri are the dominant ethnicity (caste group) making up 69% of the total population followed by Janajati (Jirel, Sherpa, Tamang) (20%) and Dalits (Damai, Kami, Sharki) (11%). There are 40% joint[4] and 60% nuclear[5] families (**Table** 1). Nuclear families are highest in Janajati (83%) followed by Dalits (60%) and Brahmin/Chhetri (53%). The average Dalit family size (both joint and nuclear) is larger than that of the two other ethnicities (**Table** 1).

Extent of migration by ethnicity

Most households (92%) in the study site have at least one or more family member residing outside of the village at least for the period of 6 months (**Table** 1). At least one member migrating outside the village is highest (100%) in Brahmin/Chhetri ethnicity followed by Dalit (80%). Lowest is in Janajati households (72%) with migrant members residing outside the village. In Jungu, short-term migration is common for man who tends to seasonally migrate to Kathmandu, the capital city or in India as non-agricultural labor work. Short-term migration trend is most common among Dalits households while long-term or overseas migration is common among elite castes such as Brahmin and Chhetri.

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[3] Unceasing out residence (either for work or higher education) for more than three months is considered as influential migration which impacts directly on farming and household level decision making (considered as per the suggestions from KIS and FGD 2015).

[4] Families residing together with more than two generations

[5] Families residing together with only one or two generations

Table 1. Family size and ethnicity with frequency of households as migrants in Jungu 2015

Family Size*	Brahmin/Chhetri	Dalit	Janjati	Total
Nuclear	4.8 ± 0.9	5.5 ± 0.8	4.8 ± 0.5	4.9 ± 0.2
Joint	7.4 ± 0.4	7.5 ± 1.2	6.3 ± 1.7	7.3 ± 0.4
Total	6 ± 0.3	6.3 ± 0.7	5.1 ± 0.5	5.8 ± 0.2
HHs with Migrants**	62 (100)	8 (80)	13 (72)	83 (92)

**Average number of family members ± Standard error (SE) of mean ** Number of HHs that have at least one or more migrating family member. Figures in parenthesis are percentages of their respective columns.*

Extent of influential migration by gender

About half of the households (49%) have influential migrants (residing out of the family for more than 3 months) with the average number of two members per households. Among households that have influential migrants, the percentage of households with only men migrants is higher than those with only women migrants (**Figure** 3).

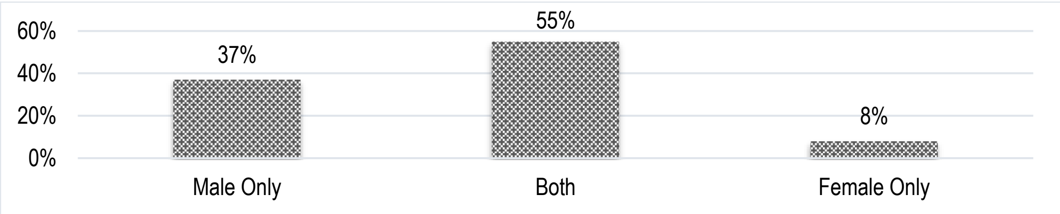

Figure 3. The percentage of households with influential migrants.

Male out-migration is prevalent in the community when there are options for higher off-farm working opportunities, higher education, better social networks and connections in migration destinations. Higher male outmigration has created the situation of *de facto* women household heads in Jungu village which follows the national scenario that women headed households in the country have increased from 14.87% in 2001 to 25.73% in 2011 (CBS 2011). As a result, women are forced to manage multiple roles including family caring, farming, maintain social relationship and other household chores.

Research showed that 93% of women family members are involved in agriculture, whereas only 61% of men members are engaged in farming activities in Nepal (CBS 2011). Increased on-farm workload for women and left behind family members have forced to decrease in the area of cultivation of traditional crops. The situation is explained by one of the key informants (Responded 09, man household head):

"*As most of the youths are out of village, labor shortage has led to reduction in cultivated lands. Especially traditional and more labor demanding crops are being dropped. In my own household, me, my wife and two daughters in-law work and we are suffering from same problem.*"

In general, couple migration is comparatively common in nuclear families, though only man member migration is predominant in joint families. Due to influential migration, only man migration is contrastingly higher than only woman migration (**Figure** 3). Socio-cultural norms and gender specific responsibilities are the key factors behind dominant man migration in Jungu. Longer-term man migration has led to on-farm labor crisis as well as increase in the workload for women who are generally left behind members in Jungu that also correspond with the study finding of Pudasaini et al (2016). Due to labor scarcity, wage labor in agriculture has increased significantly. It seems like buying agriculture product from market is cheaper than producing by farmers themselves in their farms using outside labor. The situation has triggered farmers to leave their land barren and buying foods from the market which is explained by one of the woman key informants (Respondent 025, woman household head):
"My husband and son work in Kathmandu, we (herself and her daughter) are not able to cultivate all of our land and we don't even need too. I have shared-out some productive lands and abandoned most of the low productive lands. I have kept some goats for easy working and fast cash income".

The statement is supported by the result obtained from analysis of crop growing area and richness of four traditional important crops of the VDC. There were noticeable differences in area, diversity richness of major staple crops (rice and finger millet) and diversity richness of culturally important crops (barely and buckwheat) among households with migrants and non-migrant members (**Table** 2). High labor requirement in these crops, farm labor shortage within families due to induced out-migration and increased ability of purchasing goods have led to decrease in the area of traditional crops which is also the findings of Pudasaini et al (2016). Comparatively, households having influential migrants have lower area and richness of local crops indicating a direct impact on traditional farming systems and on farm conservation of local crops.

Table 2. Impacts of influential out-migration in area and richness of traditional crops in Jungu, 2015

Crop	Richness*			Cultivation Area**		
	Community Level	HHs with Migrants	HHs with no Migrants	Community Level	HHs with Migrants	HHs with no Migrants
Finger millet	2.8 ± 0.09	2.6 ± 0.09	3.3 ± 0.17	3.5 ± 0.19	3.28 ± 0.22	4.2 ± 0.32
Rice	1.5 ± 0.08	1.4 ± 0.08	2 ± 0.16	4.9 ± 0.45	4.5 ± 0.68	5.7 ± 0.62
Barley	1 ± 0	1 ± 0.05	1.2 ± 0.11	1.1 ± 0.19	0.9 ± 0.22	1.2 ± 0.11
Buckwheat	1.4 ± 0.08	1.1 ± 0.11	1.5 ± 0.1	2.4 ± 0.64	1 ± 0.29	2.3 ± 0.54

**Average varietal richness ± SE of the mean; **Average area in Ropani ± SE of the mean. Ropani is a local unit for land area measurement which is equivalent to 508.5 meter square.*

Traditionally, men are involved in farm management, storing and marketing of agricultural products which demand more decision-making skills, knowledge and are associated with economic incentive (Tamang 2011, Paudel et al 2012). Research showed that significantly higher numbers of households having migrant family members have higher level of sole women members' involvement in farming system (**Table** 3). An important fallout of out-migration is that agricultural labor is being increasingly feminized (Kelker 2009, Kollmair 2011) which complies with the situation of study area. Women farmers' involvement is significantly higher (46%) in migrant households as compared to non-migrant households (15%) in **Table** 3.

Table 3. Frequency of households considering gender-wise involvement in on-farm works

Gender involvement	Households with influential Migrants	
	Yes	No
Women only	20 (46%)*	7 (15%)
Both men and women	24 (54%)	39 (85%)

** significant Chi test = 9.791 (p=0.002). Figures in parenthesis are HH percentages of their respective columns.*

Test statistics showed that there is significant shift in gender roles, in regard to decision making in farming matters, among households who had influential migration (**Table** 4). Traditionally, women used to be more involved in tedious and time consuming tasks of farming and had less participation in decision making roles (Thakur et al 2001) but after the migration of man family members, considerable participation of women members on household and farm level decision making has been observed ie farming system is being controlled by women family members. In the context of influential migration, significant numbers of household's decisions were made by only women members (**Table** 4).

Table 4. Frequency of households with gender wise decision makers on farming matters

Gender	Influential Migration	
	Yes	No
Women Only	22 (50%)*	12 (26%)
Men Only	5 (11%)	11 (24%)
Both	17 (39%)	23 (50%)
Total	44 (49%)	46 (51%)

** significant Chi test = 6.050 (p=0.049). Figures in parenthesis are HH percentages of their respective columns.*

Evidence shows that male out migration has multi-dimensional impacts on women's role in agriculture and household level responsibilities (**Figure** 4) which is also supported by several past studies (Gartaula et al 2010, Maharjan 2010, Devkota et al 2016). As a result of male family member out-migration, women have broadened and expanded their involvement in agricultural work and household decision making as they are increasingly shouldering the responsibilities for household survival which is also supported by Gartaula et al (2010). It is also supported by the statement of another key informant (Respondent 02, coordinator of ward citizen forum):

"*Migration have both positive and negative impacts on women members of households, there is increasing roles, responsibilities and workload but also have got opportunities to move with their own decisions. Women's participation in community institutions like in cooperative, mothers' groups and other social issues have been increased as they became 'de facto' household heads. Their control over agricultural matters and financial matters have been increased due to man out- migration."*

Traditionally, women are mostly involved in post-harvest processing of agricultural products like threshing, cleaning, drying and storing of crops (Thakur et al 2001) which is still persistent even in the context of out-migration in Jungu. Changes in involvement of women farmers in post-harvest processing was observed low (**Figure** 4) ie post-harvest processing greatly relies on part of women farmers.

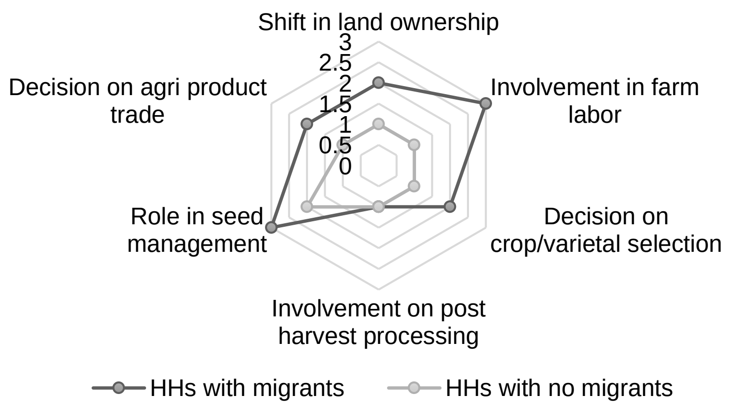

Figure 4. Perception of farmers on the shift in gender specific roles at households with influential migrants.
Changes ranking scale: 1- low, 2- medium and 3- high. Source: FGD 2016.

CONCLUSIONS

Out-migration is a most common phenomenon in Jungu village which is predominantly in part of man and is influenced by ethnicity and socio-cultural settings. Influential out-migration has led to gender specific socio-economic changes at household level decision making and farming related matters. Especially in the case of long-term migration, women family members are obliged to involve and continue traditional farming system with higher degree of contribution in terms of labor input as well as decision making roles. Migration induced shift in gender specific roles both at the household and farm level have put women members at the frontline of farming which has making them a key determinant and sole manager of traditional farming system with a tendency of feminizing farming system in Jungu village. Therefore, traditional farming systems greatly rely on women farmers in the context of long-term out-migration suggesting need to engage women farmers in research and development processes and provide additional support services to motivate those continuing farming activities. Policy support through both direct and indirect incentives measures are essential to support and promote efforts of women farmers in conservation and use of agrobiodiversity in mountain farming systems (Gauchan et al 2020). Changed social contexts and feminization induced by out-migration needs to be recognized from formal sectors, development agencies and policy makers which are intended to work in traditional or rural farming system. Clearly defined gender responsive strategies, programs and implementation would be effective. Focus should be given to empowerment of women, their training and participation in decision making, women drudgery reduction in farming and post-harvest processing, women farmer friendly extension tools, and access to information and services to improve the productivity and welfare of women in light of man out-migration and feminization in agriculture.

ACKNOWLOGEMENTS

This study was a part of Local Crop Project funded by UNEP-GEF and implemented by Bioversity International, NARC, DoA and LIBIRD. The authors acknowledge all the stakeholders and farmers for their assistance and support during the study.

REFERENCES

ADB. 2013. TA 7762-NEP Preparation of the Agricultural Development Strategy - Final Report. Asian Development Bank. http://www.adb.org/projects/documents/agricultural-development-strategy-final-report

Baidya SK, ML Shrestha and MM Sheikh. 2008. Trend in daily climatic extremes of temperature and precipitation in Nepal. Journal of Hydrology and Meteorology **5**(1):38-51.

Chant S and C Sweetman. 2012. Fixing women or fixing the world? Smart economics, efficiency approaches, and gender equality in development. Gender and Development **20**(3):517-529.

Cornhiel S. 2006. Feminization of Agriculture: Trends and Driving Forces. Background Paper for the World Development Report. Rimisp-Latin American Center for Rural Development.

CBS. 2011. National Living Standard Survey (NLSS) 2010/11. National Bureau of Statistics, National Planning Commission, Government of Nepal. Kathmandu.

Devkota R, K Khadka, H Gartaula, A Shrestha, S Karki, K Patel and P Chaudhary. 2016. Gender and labor efficiency in finger millet production in Nepal. **In**: Towards Transforming Gender and Food security in the Global South (J Njuki, J Parkins and A Kaler, eds). New York: Routledge; **pp**. 7-26.

FAO. 2011. The State of Food and Agriculture 2010-11. FAO, Rome, Italy.

Gartaula HN, A Niehof and L Visser. 2010. Feminisation of agriculture as an effect of man out migration: Unexpected outcomes from Jhapa district, eastern Nepal. The International Journal of Interdisciplinary Social Sci. **5**(2):565-577.

Gauchan D. 2008. Agricultural development in Nepal: Contribution to economic growth, food security and poverty reduction. Socio Economic Development Panorama **1**(3):49-64.

Gauchan D, BK Joshi, B Bhandari, N Pudasaini, R Gurung, KH Ghimire and KK Mishra. 2020. Incentive measures for agrobiodiversity conservation and Use. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gautam TR. 1999. Labour Migration to India: A Case of Kandebash VDC, Baglung. A dissertation Submitted to Sociology/Anthropology, TU, Kirtipur

Honsberger A. 2015. Professionals in their field: Women vegetable farmers in Nepal (Master's thesis). Retrieved from http://hdl.handle.net/10214/8776

IFAD. 2000. Gender Perspective: Focus on the Rural Poor. An Overview of Gender Issues in IFAD-Assisted Projects. Rome: IFAD. http://www.ifad.org/pub/ gender/engl.pdf.

IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Kelker G. 2009. The Feminization of Agriculture in Asia: Implication for Women's Agency and Productivity. New Delhi.

King R. 2014. Theories and Typologies of Migration: An Overview and a Primer. Willy Brandt Series of Working Papers in International Migration and Ethnic Relations 3/12 Malmo University, Sweden.

Kollmair M. 2011. Labour migration in the Himalayas: Opportunities and challenges. Sustainable Mountain Development 59:..

Lal R. 2009. The plow and agriculture sustainability. Journal of Sustainable Agriculture **33**:66-84.

Maharjan A. 2010. Labour out migration and its impact on farm families in the mid hills of Nepal. **In**: Farming and Rural Systems Economics (W Doppler, and S Bauer, eds). Volume 113, Margraf Publishers, Germany.

Malla G. 2008. Climate change and its impact on Nepalese agriculture. The Journal of Agriculture and Environment **9**:62-71.

Mrunalini A and Ch Snehalatha. 2010. Drudgery experiences of gender in crop production activities. J. Agric. Sci. **1**(1):49-51.

Paudel KP, D Dahal and R Shah. 2012. Abandoned Agricultural Land in Mid Hills of Nepal. Kathmandu: Forest Action Nepal and IUCN-Nepal.

Pudasaini N, SR Sthapit, D Gauchan, B Bhandari, BK Joshiand BR Sthapit. 2016. Baseline Survey Report*:* I. Jungu, Dolakha. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity Internationa.

Tamang S. 2011. Feminisation of agriculture works and its impact on health status of women and their family health (for the fulfillment of thesis for Master's degree), Patan Multiple campus, Tribhuwan University, Nepal (unpublished).

Tamang S, KP Poudel and KK Shrestha. 2014. Feminization of agriculture and its implications for food security in rural Nepal. Journal of Forest and Livelihood **12**(1):20-32.

Thakur S, SK Varma and PA Goldey. 2001. Perceptions of drudgery in agricultural and animal husbandry operations: A gender analysis from Haryana State, India. Journal of International Development **13**(8):1165-78.

Upadhyay B. 2005. Women and natural resource management: Illustrations from India and Nepal. Natural Resources Forum 29(3):224-32.

World Bank. 2009. Gender in Agriculture Sourcebook. Washington, DC: World Bank.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D I Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Organic Farming and Marketing of Traditional Crops in Nepal Mountains: Gaps, Issues and Opportunities for Improvement

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ABSTRACT

Organic farming that respects human and environmental health is promoted in Nepal and globally as an agricultural production alternative to conventional agrochemical-based farming. This study documents the current state of organic farming and marketing and identifies gaps in policies, practices and program activities for the production, processing and marketing of traditional nutrient-rich mountain crops of Nepal. The study employed a structured field survey of 32 organic producers and retailers, key informant interviews of stakeholders and a case study of organic farmers in the high mountain organic district of Jumla. We reviewed national policies, legislations, standards and programs focusing on organic farming and marketing. Results showed that organic certification is practiced mainly in production and marketing of some high value crops but not in underutilized traditional nutrient-rich food crops, such as buckwheat, barley, millets and beans, even though products of these crops with organic labelling is found in major urban markets. Small farmers cultivating and marketing traditional mountain crops have very limited awareness on the process, policies, standards and certification procedures. The cost of organic certification is very high and farmers have poor access to organic technologies. As a result, traditional underutilized crops, which constitute staple food of high mountain agriculture have not benefitted from the current organic policies and provisions. Policy options, legislations and promotional programs in combination with specific incentive mechanisms and technological supports are necessary for the production, processing and promotion of traditional nutrient-rich food crops in Nepal mountains.

Keywords: Incentives, marketing practices, organic agriculture, policy gaps, traditional crops

INTRODUCTION

Organic farming has been identified as an environmentally friendly option for increasing income, reducing environmental pollution and soil erosion, conserving water and biodiversity and improving human health (IFOAM 2010, UNEP 2011). The area under organic agriculture is growing rapidly worldwide in recent years with nearly 7 folds increase from 11 million hectares in 1999 to 71.5 million hectares in 2018 (FiBL and IFOAM 2020).The market research company, Ecovia Intelligence, estimates that the global market for organic food surpassed 100 billion US dollars for the first time in 2018 – an increase of 6% from the year before and keeps showing double-digit growth rates in different countries (https://www.organicwellnessnews.com/?ArticleID=941). The United States is the leading market, followed by Germany and France. Globally, 97 countries have organic legislation, where the majority of organic production, marketing and certification is practiced predominantly for high value export crops (FiBL and IFOAM 2020).

Organic agriculture is an ecological production management and farming system that bans the use of agrochemicals, such as synthetic fertilizers and pesticides, and prohibits the use of Genetically Modified Organisms (GMOs) and many synthetic compounds used as food additives (IFOAM 2008, 2010). A recent review from a meta-analysis of a global dataset spanning 55 crops grown on five continents showed that despite their lower yields, organic farming systems are significantly more profitable compared with conventional agriculture when organic price premium are considered (Crowdler and Reganold 2016). Similarly, other studies also have shown the relative profitability of organic farming as against conventional farming when prevalent price premiums are taken into consideration. For instance, in the United States, organic farming has been shown to be 2.7 to 3.8 times more profitable for the farmers than conventional farming where prevailing price premiums are considered (Moyer 2013). They are also environmentally friendly, and deliver greater ecosystem services, social benefits and more nutritious foods that contain less (or no) pesticide residues, compared with conventional farming (Crowder and Reganold 2016). Moreover, organic agriculture in developing countries builds on and keeps alive farmers' rich heritage of traditional knowledge and traditional agricultural varieties (UNCTAD/UNEP 2008). Hence, organic agriculture can help meet multiple sustainable development goals such as achieving zero hunger, improving human health, combating climate change, biodiversity protection, sustainable land use and clean water.

Considering these environmental, social, economic and health benefits of organic farming and marketing potential, the Government of Nepal has developed some policies, guidelines, standards and programs for supporting organic agriculture, that are rather fragmented. The objectives of these national policies, guidelines, standards and programs are to promote and regulate organic agriculture production and processing and provide support to export market of Nepalese agroproducts. At the same time, they are aimed to increase income of farmers and agroentrepreneurs by safeguarding environment and human health. As organic agriculture builds on the comparative advantage of poor farmers practicing traditional agriculture in less contaminated marginal lands, linking these organic farmers to global value chains can potentially offer them the benefits of higher income and improved health, while involving them as part of the solution for climate change and enhancing their climate resilience and food security (ADB 2015). However, we have limited understanding and information about the status of organic farming and marketing including the content and provisions of the government policies, plans, guidelines, standards and programme activities on the promotion of organic farming, marketing and maintenance of local mountain crop diversity in Nepal. In this context, this study aims to (i) document the current state and practice of organic farming and marketing (ii) assess drivers implementing organic agriculture in Nepal (iii) identify gaps in policies, guidelines and standards in production, processing and marketing of nutrient-rich local crops and (iv) suggest appropriate actions and interventions for promoting traditional mountain crops and varieties in the mountain regions of Nepal.

METHODOLOGY

The study has employed desk review of organic policies, standards and guidelines combined with field survey of key stakeholders engaged in organic production, input suppliers and marketing. Field data collection was accomplished employing combination of sample interviews, key informant survey and narrowly focused case studies carried out in the mountain agroecosystem. Specific procedures employed were (i) survey of organic producers, input suppliers and traders in 8th National Organic Fair in Pokhara in 2015 (ii) key informant interviews of organic traders, R & D professionals and entrepreneurs in Pokhara and Kathmandu valleys and (iii) narrowly focused case study in Jumla – an officially declared organic farming district of Nepal. Survey questionnaires and checklists were prepared separately to implement field survey to collect data and information for these three sets of methods. We conducted sample interviews of 26 organic stalls representing producers and traders from a total of 94 stalls demonstrated in the 8th national organic fairs held in Pokhara from 20 January to 1 February, 2015. We also conducted interview of selected producers, retailers and entrepreneurs (survey of 12 organic stores and market places) and Jumla (n=12 stakeholders). The data and information generated from the field surveys were compiled, analysed and interpreted.

FINDINGS AND DISCUSSION

Traditional food crop production system

Agriculture in the high mountain region of Nepal particularly for traditional underutilized crops has remained organic by default based on the inherent traditional integrated farming system and remoteness which provides a strong foundation for organic agriculture development. A recent study of mountain agricultural systems in four representative high elevation mountain agroecosystems in Nepal indicated that farmers are not using agrochemicals in the production of traditional mountain crops (Gurung et al 2016, Pudasaini et al 2016, Parajuli et al 2017, Palikhey et al 2017). The study also reported that farming system is dominated by traditional crop varieties, where except small proportion of area in high altitude rice, all of the farm area in buckwheat, barley, beans, millets and amaranth were occupied fully by traditional varieties. Similarly, 97% of the seed requirements of the farm households in the mountain region is mainly met through farmers' own seed system or informal seed system, where farmers meet their seed requirement through own saving, community exchanges and local informal markets (Gurung et al 2020). This informal seed system and traditional farming practices makes resource-poor farmers less dependent on external inputs or resources, helps them enjoy more stable yields and income, and ensures local household food security.

Furthermore, mountain agriculture is dominated by smallholder subsistence farming with integrated crop-livestock agroforestry system. The use of external chemical inputs is not required for traditional subsistence crop production and even if required, they would be either very expensive or not easily available and beyond the reach of smallholder farmers. The use of agro-chemicals is becoming important only to some accessible lower hills and valleys of central mountainous region particularly for major crops (rice, wheat, maize) and the high value cash and horticulture crops (Pokhrel and Pant 2009). A recent survey covering whole of mountain regions (including middle and lower hills) showed that farmers use a very limited quantity of fertilizer constituting 13 kg of synthetic N fertilizers per hectare particularly for major food crops (rice, wheat, maize) and high value horticultural crops such as vegetables, fruits and potato (Takeshima et al 2016). The use of pesticides is also very much limited in the mountain agroecosystems with 7% household using in only 0.7 percent of land area (PRMS 2014).

Drivers of organic agriculture in Nepal

The major drivers of organic production and marketing in Nepal include increased awareness on health and environmental benefits and economic benefits from organic production and marketing. Environmental benefits include improved soil fertility and low chemical pollution. Consumers' concern about food safety and willingness to pay for the quality organic foods are also drivers of organic agriculture movement in Nepal which started early 1990s (Aryal et al 2009, Pokhrel and Pant 2009). Perceived economic benefits from organic farming (when the products are linked to market) is also another important driver of organic farming due to higher profitability resulting from increased price premium of organic products and use of low external input costs. The opportunity for relatively better employment opportunities from organic farming and marketing in production and marketing is also another perceived benefit. In recent years, urbanization, increase in remittance income and the growth in tourism sectors have also promoted organic production and marketing of agro-products. Price premium for organic products is also a driver for producers and traders to engage in organic business.

Even though, default organic farming without the use of agrochemicals is estimated to be quite high particularly in the mountains and remote hills, formally certified organic farming is limited, which constitutes 11,951 ha of land in 2018 (FiBL and IFOAM 2020) accounting for about 0.3% of the total agricultural land in Nepal. Initially organic farming took momentum with the objectives of export of high value agriculture (e.g. tea, coffee, honey, ginger, cardamom) and the rejection of large export consignment of honey from Nepal in Europe in 2002 due to the presence of chemicals in the exported products (https://thehimalayantimes.com/business/honey-exports-to-eu-likely-to-resume/). Nepalese consumers are willing to pay higher price for local specific organic mountain products such as apple and beans of Mustang and Jumla, mandarin orange from Gorkha, orthodox tea from Ilam hills, and coffee from western and central hills. However, the consumers' willingness to pay is not yet regularized to protect consumer rights and lots of adulteration happens at retailer's level. With the beginning of 2000s, the Government of Nepal started supporting organic agriculture through some policy provision and subsidies for input subsidy (eg subsidy in organic manure), export subsidy for cash crops (MoAD 2013) and declaration of organic district for Jumla in 2007. The support to organic agriculture also includes creating enabling environment for certification by allowing various national and international agencies in certification process. The objective is to differentiate the preferred quality organic products from other products, resulting in the promotion of organically grown products in the market.

Practices of organic marketing in Nepal

The major organic products produced and marketed in Nepal include mainly cash crops (eg tea, coffee, large cardamom, ginger, fresh vegetables, honey and herbal products). Organic certification of local underutilized mountain crops (eg beans, buckwheat, naked barley, cold tolerant rice, millets and amaranth) is very much limited. However, recently marketing of traditional products is being initiated in small scale in some of the supermarkets, organic retail chains, food fairs and health food stores in urban areas of Kathmandu and Pokhara. It is currently emerging as a 'niche' or 'specialty' product for natural indigenous wholesome foods from mountain region, where suitable high altitude cold climatic conditions are available. Traders and organic retailers normally buy these traditional mountain crop products through local traders and collectors or directly from producers (farmers' groups or cooperatives) and process and sell them to retailer shops in urban markets (**Figure** 1). These traditional mountain products are also informally traded to foreign countries where non-residents Nepalese people and migrant workers are residing for their local consumption. However, value chain for these traditional underutilized crops is weak, fragmented and not well developed (Gauchan et al 2019). Underutilized traditional crops are marketed as organic products informally not through formal certification process but mainly through self-labeling as organic products. Formal marketing and export of organic-certified products is mainly found for high value cash crops such as coffee, tea and cardamom.

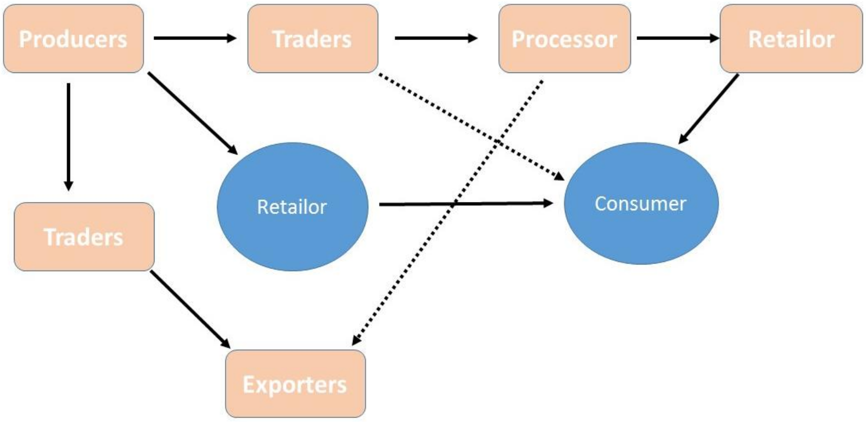

Figure 1. Practices of organic marketing channels in urban areas of Nepal.

Many of the traditional crops are marketed using local labeling of origin of the products such as Jumli organic red rice, Jumli and Mustang beans and buckwheat. The available information also reveals that organic-certified agroproducts of high value crops receive 40-100% higher prices than non-organic products (Gurangain 2014). For traditional mountain crops, market survey assessment in Kathmandu valley showed that consumers are willing to pay 30-50% higher price if they are organically certified and labeled with nutrition and health value and products of high mountain origins. For some retailers and supermarkets, organic buckwheat flour and bean from Mustang were sold for 100% higher prices compared to those not organic-labeled and originated from lowland. The users and consumers of these traditional organic products were mainly tourists, relatively old-aged higher income groups with their earlier consumption habits and food preferences that are migrated from rural hill and mountain areas.

Recently, some of the high-income urban families, who suffer from diabetes, high blood pressures and obesity are also increasingly attracted to consume these products. Rapid appraisals of the markets also revealed that young generation are not much interested to consume traditional food products as they do not have food habits and better knowledge of positive nutritional and health effects of these products. Many of the urban people have limited knowledge of the availability of such products and lack better nutritional value of these products. Recently, few of the modern restaurants in Kathmandu valley and in the major highways and urban centers have increased tendency to serve food menu of the local mountain products (eg buckwheat *dhindo,* beans soup or *daal*) to satisfy old-aged, middle and high income urban-based consumers. However, marketing of traditional crop varieties and underutilized crop species in most of the mountain environments is constrained by poor access to postharvest processing technologies, information and adequate knowledge of potential market demands.

National policies, programs and guidelines on organic farming

The policy supporting organic farming and marketing in Nepal started only after year 2000s specifically with the formulation of the Tenth plan (2003-2007) and subsequently with the approval of National Agriculture Policy (2004), which has provisions to support organic farming, marketing and organic products certification. The list of policies, plans, strategies, and guidelines supporting organic agriculture in Nepal is presented in **Table** 1. The Agriculture Development Strategy (2016-2035) also envisions organic farming as one of the Good Agricultural Practices (GAPs) for sustainable production system. Agribusiness Policy (2006) has also recognized organic farming with focus on marketing of high value export crops. Agrobiodiversity Policy (2007) revised in 2014 envisages promotion of agrobiodiversity conservation with organic and ecofriendly farming systems. The national plans such as the 14th National Plan (2016/17-2018/19) and the recently formulated 15th National Development Plan (2019/20-2023/24) specifically mention developing priority programs for organic agriculture development.

Considering the importance of organic agriculture, the Ministry of Agricultural Development (MoAD) in 2007 developed "National Standards of Organic Agriculture Production and Processing" (2007) and revised in 2008

(MoAD, 2013). In addition, the Ministry also developed "Procedures for Export of Organic Certification Agro-products Cash Subsidy (2013)" to provide export subsidy of organic products.

Table 1. **Policy, plan, strategy, guidelines and their organic focus and content in Nepal**

Policy, Plan and Guidelines	Organic focus/content	Gaps and Issues
National Agricultural Policy (2004)	Organic agriculture production, certification and export	No specific implementation action plans and no Geographical Indication (GI) focus
Agribusiness Policy (2006)	Organic agriculture marketing and export	No specific implementation and action plans for organic farming
Agrobiodiversity Policy (2007) revised 2014	Organic agriculture for agrobiodiversity conservation	Just mention made for organic but no details on standards
National Standards for Organic Agriculture Production and Processing, revised version (2008)	Standards for organic agriculture and processing	Broad guidelines for crop but not specific guideline for traditional crops and no GI focus
Procedures for Export of Organic Certification Agro-products Cash Subsidy (2013)	Cash subsidy for export of organic products (10-30% subsidy in total revenue)	Focus on export subsidy but not for production subsidy
Agriculture Development Strategy (2015)	Good Agricultural Practices (GAPs) and organic agriculture	Focus on GAPs, no action plans for Organic and GI
Organic Agriculture Promotion Mission Programme Implementation Procedure (2018)	Focus on use of both organic and traditional crops and products free of chemical pesticides	The program is being implemented only in selected 12 districts of province 2, 3 (Bagmati) and 4 (Gandaki).

There is also a guideline developed in 2011 for import, export and sales to promote use of organic manures for organic agriculture as well as organic fertilizer subsidy (district level) guideline approved by the Ministry of Agriculture in May 2015. Recently, both national and provincial governments of Nepal have shown interest in the promotion of organic agriculture. As per the 58 road map of the federal Ministry of Agricultural and Livestock Development (MoALD), the Department of Agriculture is implementing Organic Mission Program in 12 districts and Indigenous Crop Promotion Program in 3 districts since 2018. Other good initiatives towards the promotion of organic agriculture are the recent formation of a high-level task force in Organic Agriculture at the national level by the federal Ministry of Agricultural and Livestock Development in 2018 (https://www.moald.gov.np/highlevel-taskforce) and organization of International Organic Workshop that developed foundation for promotion of organic agriculture in Nepal (MoALD 2019). Recently, the Government of Nepal also imposed restriction on the import of vegetables, fruits and other agroproducts that have high pesticide residue from the neighboring countries (especially with India that have long borders) but discontinued later. The government has also endorsed and implemented some other relevant Acts and Regulations such as Pesticides Act (1991) and Pesticide Regulation (1994), Environment Protection Act and Environmental Protection Regulation (1997) that envelop some aspects of organic agriculture (Shrestha and Pant 2006). However, the Government of Nepal has yet to develop comprehensive policy, legislation and set up institutional mechanisms to gear organic farming and marketing building on present policies and procedures on organic agriculture, which are rather fragmented and poorly implemented.

Organic standards and status of organic certification in Nepal

The provisions described in "Standards of Organic Agriculture Production and Processing 2008 (2065)" of the Government of Nepal provides broader framework for crops, livestock, fishery, and apiculture. The key provisions of national standards are presented in Box 1.

Box 1. Key provisions of national standards of organic agriculture, Nepal

1. The standard prohibits chemical contamination in production, transfer and processing and use of GMOs and radioactive devices.
2. The standard limits use of fertilizers and contaminated manure and emphasizes use of local variety, organic seed source and no chemical seed treatment.
3. The standard also avoids torturous raring, fetal implantation, cloning and hormonal use in animal production.
4. The standard protects farmers for fair remuneration and employees and consumers for their rights.
5. The standard consists of structural arrangements for organic certification and specifies land arrangement for organic production.

Source: Literature review (2019)

Although endorsed by the MoALD of the Government of Nepal, these standards continue to remain voluntary because Nepal has yet to enact national legislation on organic production and marketing. The current standard requires four years for conventional system to transform fully to organic agriculture**.** Farm facilities and production methods must comply with the standards prescribed in the system. The process requires extensive paperwork, detailing farm history and current set-up, including results of soil and water tests. Organic standards also require farmers to use organic seeds and encourage genetic diversity in both crops and livestock (Khanal 2009). The standards for certification emphasize the use of local variety, organic seed source and fair remuneration to farmers, which is favourable to promotion of traditional native mountain crops. However, as compared to international standards such as European Union (EU) or the United States Department of Agriculture (USDA), this national standard is very broad with no specific standards for the acceptance level or allowance limit of organic food percent (with accepted level of chemicals and GMO level). It has also no clarity on whether focus is on the process or end product**.** The major international standards such as of EU and the USDA indicate allowance level of GMO should be less than 0.9% and food free of chemical should not be less than of 95%.

The demand for organic certification is gradually increasing in Nepal although it is in early stage (Ranabhat, 2009). With increased market demand and premium price of organic products, recently farmers from different parts of the country are getting interested in organic farming and marketing. As per the information of Organic Certification Nepal (OCN), altogether 2,454 farmers had certified their produce by mid 2014 (Gurangain 2014). The OCN also reports that 995 farmers from Jumla, 207 from Palpa, 294 from Kaski, 800 from Kavre, 80 from Dadeldhura and Ilam had certified their products by mid 2014. Likewise, nine farms have also been certified as organic (http://www.myrepublica.com/portal/index.php). Some of the agriculture products that most recently have private organic certification include apples produced in Jumla, honey of Dadeldhura, Coffee of Kaski, rice of Chitwan, vegetables of Kathmandu, lentils of Rasuwa, and tea of Ilam (Gurangain 2014).

Status of organic production and marketing

Market for organic products is quite rudimentary with limited branding and certification. Third party certification is a recent phenomenon. Most of the organic production and marketing system has been operating on the basis of trust. Traditional mountain crop products are mainly sold with self-labeling as default organic products. Survey of producers and traders in the 8th National Organic Fair in Pokhara from January 29 to February 1, 2015 revealed that only 13% of the sample producers and 27% of the traders had officially certified their products (**Table** 2).

Table 2. Results of organic producers and traders' survey in the 8th National Organic Fair, Pokhara, 2015

SN	Type	Number of groups and traders	Number of surveyed stalls	Level of awareness on certification	Status of certification (% sample with certified product)
1.	Farmers and farmers' group (Producers)	71	15	33	13
2.	Agri-business (Traders)	23	11	36	27
	Total	94	26	35	19

The organic production, sale and certification were seen mainly in cash crops (coffee, tea, ginger, honey and vegetables) and specifically targeted for export purposes. Most of the products of traditional mountain crops are not officially certified but they are often sold with organic labeling in organic stores and departmental shops in Kathmandu and Pokhara. Participatory Guarantee System (PGS) is also not practiced in traditional underutilized mountain crops. The level of awareness of organic certification was also limited among producers and traders. The survey of producers and traders in National Organic Fairs also revealed that only one-third of the sample organic producers and traders selling organic products were aware of institutional level certification processes.

Case study of mountain crops from Jumla - An organic-declared district

Jumla is the first "Organic District" officially declared in 2007 for the implementation of organic agriculture in Nepal. As an organic district the district administration has banned the import and use of chemical fertilizers and pesticides for production of fruits, vegetables and food crops. The rationale for implementation of organic farming was to obtain higher income from locally produced high value agricultural products (apples, beans, potato etc) without harming the environment and local mountain ecology. Presently only apple is officially certified and sold from Jumla as an organic product. Traditional crops such as Jumli red rice, beans, buckwheat, barley and millets (finger millet, proso millet, foxtail millet) have also important scope for organic production and marketing. The traditional Jumli rice[6] has its unique local and global importance because of its cold tolerant genes that help in adaptation to harsh cold environment of high-altitude mountain region.

There is a potential to market this rice variety with organic and GI logo both domestically and internationally similar to organic red rice of Bhutan being exported in international market. However, production of this traditional rice variety is declining recently with increased incidence of diseases and its labor-intensive production practices. Banning of agrochemicals has restricted use of pesticides for weed and pest control respectively. Farmers, particularly women, are overburdened with increased drudgery for weeding and managing pest and diseases in the absence of suitable organic technologies. As a result, production of traditional crops like millets (finger millet, proso millets, and foxtail millet), amaranths, barley and buckwheat are declining with changing food habits and in the absence of appropriate labor-saving production and processing technologies (Palikhey et al 2017). Farmers also lack technical support and training on organic production, seed management, disease and pest control and processing of crops. Deforestation, youth migration and declining tendency of raising livestock in the farm households are also other emerging challenges putting constraints in the implementation and promotion of organic farming. Therefore, for the promotion of organic farming, introduction and adoption of drudgery reducing processing and cultivation technologies, and incentives for organic production and marketing of traditional crops, including awareness on the nutrient and health value of nutrient-rich traditional crops is essential.

Gaps, Issues and Challenges

There are several gaps, issues and challenges in organic farming particularly for smallholder farmers and local traders (**Table** 3). Some perceived gaps, issues and challenges are specific to farmers or traders while most of them are common for both of the actors. Small farmers and local traders have limited awareness in process, procedures and access to certification systems in Nepal. Even if they have access to certification agencies, the process is complicated and the cost of certification is very high beyond the reach of small farmers particularly in inaccessible mountain regions. Presently the cost of organic certification per farm (1 ha) is about NPR 130,000 (USD 1300), which is beyond the capacity of individual small farmers and small traders. The costs can be recovered if a crop is produced in a large-sized farm with large scale of production or collective certification by a group or cooperatives of farmers for their products. Moreover, smallholder farmers and local traders have difficulty to comply with quality and stringent standards required in production and processing and difficult to afford high supervision costs for third party certification. Since organic certification requires record of chemical free production process with specific standards maintained at the farm level, it is difficult for most small illiterate mountain farmers to keep the farm records that are required for organic certification. These farmers and traders have also limited awareness and knowledge of the available production and marketing technologies, practices, subsidy and support for organic production and marketing. Smallholder farmers also have limited access to technical support and services for organic technologies (eg biopesticides, biofertilizers) and information.

[6] Traditioanl Jumli rice is a principal and culturally prestigious food crop in Jumla district, which is cultivated in high mountain river valleys and hill side terraces from 2000-3050 msl. Chhumchaur (3050 msl) of Jumla district is considered the highest altitude in the world where rice is cultivated.

Table 3. Gaps, issues and challenges perceived by stakeholders for organic farming

SN	Gaps, Issues and Challenges	Producers	Traders
1	Poor awareness about certification procedures and standards	X	X
2	Limited access to certification of organic products	X	
3	High cost of certification of organic products	X	X
4	Limited of access to laboratory facilities for organic testing		X
5	Limited availability of technologies for organic production, processing, storage and marketing	X	X
6	Poor quality of farm produce for certification		X
7	Lack of support and subsidies for organic farming	X	
8	Lack of technical know-how for organic production process and farm record keeping	X	
9	Longer conversion period for organic production	X	
10	Poor technical support for organic labelling, packaging and marketing		X

Source: Field survey 2015.

They generally perceive higher risk and longer time involved in conversion to organic farming methods from the traditional method of production and processing in addition to perceived poor support and subsidies for organic production of local crops. Traders perceive that they have limited or no access of laboratory facilities for testing the quality and traceability of the chemicals and standards in the organic products as well as poor access to technical support for organic labelling, packing and marketing. There is a perception of traders that the products purchased from farmers are of poor quality and not suited for certification, when aggregated.

Opportunities

Presently mountain crops are default organic and domestically consumed for their high nutritional and health value. Portfolios of local crop varieties grown organically in the mountains match the ecological farming as it offers resilience against adversities, especially climate change by enhancing an adaptive capacity of the farming community. Since most of the farms in mountainous region of Nepal do not use chemicals in producing traditional crops and use own farm-saved seeds produced locally, conversion of their farms to organic agriculture would require relatively less time and efforts than for the commercial growers in the lowland commercial pockets in Nepal (Pant 2006, KC 2006). Participatory Guarantee Systems (PGS) are more suited for smallholders cultivating traditional crops in the remote mountains as they are cost-effective, locally focused quality assurance systems that are proved to be an affordable alternative to third party certification system (FiBL and IFOAM 2020). In this context, support from both public and private sectors are needed to mountain farmers in terms of training and networking of farmers groups, adoption of internal control system and linking them to the organic market and organic certification networks. PGS certification in mountain crops would help not only to access organic markets for increasing the income and promoting the identity of small holder farmers but also will be useful to promote the conservation and improve ecosystem services in the mountain regions.

Geographic Indication (GI) is one of the potential means to promote local mountain crops by combining with organic certifications and thus can provide a unique combination of assurance to consumers. Local agricultural products originated in the mountains have specific qualities and taste that derive from their place of production and are influenced by specific local factors such as climate, soil and culture (Joshi et al 2017). Most of such local products have very good taste and are sold in the market with high price as consumers pay premium price mainly for taste, nutrition, purity and deliciousness (Joshi and Gauchan 2020). Research on identification and evaluation of GI-linked traits of traditional mountain crop is an important step in this process. This will, however, require development of relevant legislation and the institutional framework to support and protect GI for specific local mountain crops. In many cases GIs can readily combine with organic certifications and thus provide a unique combination of assurance to consumers. Promoting different kinds of traditional and local agricultural products can be marketed as healthy local and natural foods through smart labelling and packaging as they are produced organically with no chemical inputs. Consumers today in Nepal and elsewhere show an increasing interest in natural and healthy so-called functional foods, which are defined as 'food or food ingredients that may provide a health benefit beyond the traditional nutrients it contains. Therefore, there are huge opportunities to promote these traditional mountain crops and their products with unique functional foods by combining organic production and value addition with smart branding, labeling and fair-trade marketing. The smart branding and labeling need to highlight low glycemic index and gluten-free nature of millets, buckwheat and amaranth and heart-healthy fiber in naked barley to create awareness, promote social marketing and attract wide range of consumers. Amaranth grains and buckwheat could be marketed as Himalayan superfood because of their superior amino acid profile, while their greens are good sources of iron and minerals (www.himalyancrops.org). Marketing "easy to use" products such as chapatti flour blends of diverse millets and pulses with wheat is already popular in Indian supermarkets. Similarly, flour blends that include buckwheat, barley, amaranth and other millets are timely for testing and promotion in Nepal. This is a strategy looking at nutrition from a 'whole of diet' perspective rather than from single-food, single-nutrient approach, considering the diversity within the species, between species and between different ecosystems.

CONCLUSIONS AND POLICY IMPLICATIONS

Value chain development in organic agriculture is still in its infancy in Nepal but it is increasingly gaining importance among public and private sectors recently. Since, organic farming focuses on holistic production system with integrated farming for its nutrient recycling and production sustainability, it is a means to promote biodiversity, health of human beings and provision of ecosystem services. At present, organic production and marketing systems in Nepal are mainly initiated in handful of high value export-oriented crops with the participation and facilitation of private sectors agencies and civil societies. However, producers and traders have limited level of awareness on process, procedures and process of certification for organic agriculture. There are few certification agencies but the standards are stringent and mainly focused for cash crops and export markets. The system of certification and standards for underutilized mountain crops is not available and if available the process is complicated and very costly. Trained human resources and institutions supporting organic farming and marketing are very much limited and those available are directed towards high value and export-oriented cash crops. Despite some piece meal support in policy for organic production and marketing and presence of standards and guidelines, there is no comprehensive policy, specific legislation and institutional mechanisms developed in the country for organic farming and marketing. The available support and subsidy mechanisms are focused on cash crops mainly for export purposes. Research on technology development, value addition and policy support for organic marketing of traditional crops in the mountain region is limited. Therefore, organic production and marketing of traditional underutilized crops in mountains face several constraints related to the mechanisms for setting up norms and standards, developing product guarantee and certification mechanism, including insurance services and awareness building. The processing and value addition technologies are poorly developed to meet market standards and capture organic markets with reducing risks and costs of production. Public and private advisory and extension services for production, processing and marketing is also limited. Despite, the perceived health value and importance of traditional mountain products, public support and subsidy are limited for these crops through certification, geographic indication (GI) opportunities and fair trading means.

Considering the rich biodiversity of traditional crops, mountain culture and availability of high altitude environment with little or no use of synthetic chemicals and external inputs, there is a huge potential for production and promotion of organic agriculture in the mountain regions of Nepal. Products of traditional mountain crops such as beans, buckwheat, naked barley, millets and high altitude rice have specific quality attributes, nutrition and health benefits that have already in a high demand and preferences among consumers in lowlands and urban markets. However, to promote these local crops as demanded, a strong commodity specific value chain and market linkages are needed. In this context, Participatory Guarantee System (PGS) would be a good option to promote certification of local crop products by mobilizing and enhancing capacity of smallholder farmers and local communities for meeting quality standards using internal quality control system and economic scale of production. PGS is already in operation in some locations in Nepal focusing for vegetables and cash crops. Organic farming supported with fair trade marketing and GI opportunities will further add value of traditional mountain crops with their special attributes and place of origin, thus retaining youth and improving livelihood of small-farmers and marginalized communities. Future research and development programs for organic agriculture, therefore, need to focus on comprehensive policy, legislation and institutional mechanisms to gear up with specific support programs, incentives, clearly focused guidelines and technologies for production, marketing and conservation of traditional mountain crop diversity and improving ecosystem services in the mountains.

REFERENCES

ADB. 2015. Organic Agriculture and Post-2015 Development Goals. Building on the comparative Advantage of Poor Farmers. Mandaluyong City, Philippines: Asian Development Bank (ADB).

Aryal KP, P Chaudhary, S Pandit and G Sharma. 2009. Consumers' willingness to pay for organic products. A case from Kathmandu Valley. The Journal of Agriculture and Environment **10**:12-22

Crowder DW and JP Reganold. 2016. Financial competitiveness of organic agriculture on a global scale. Proc. Natl Acad. Sci. USA, **112**:7611-7616.

IFOAM. 2008. The World of Organic Agriculture - Statistics and Emerging Trends 2008. International Federation of Organic Agriculture Movements (IFOAM), Bonn, Germany.

IFOAM. 2010. Definition of Organic Agriculture. IFOAM http://www.ifoam.org/ growing organic/definitions/doa/index.html, and http://www.ifoam.org Accessed on 10 March 2010.

FiBL and FOAM. 2020. The World of Organic Agriculture. Statistics and Emerging Trends, 2019. FiBL, IFOAM Report. Research Institute of Organic Agriculture (FiBL), Frick and International Federation of Organic Agriculture Movement (IFOAM), Bonn.

Gauchan D, B Bhandari, R Gurung, BK Joshi and D Jarvis. 2019. Value chain development of underutilized food crops for nutrition sensitive agriculture in the mountains of Nepal. **In**: Proceeding 5th International Agricultural Marketing Conference, Kathmandu, June 4-5, 2018. Nepal Agricultural Economic Society (NAES), Ministry of Agriculture and Livestock Development (MoALD), FAO, KISSAN-2, USAID, Nepal.

Gurangain M. 2014. Organic Certification in Nepal, My Republica. http://www.myrepublica.com/portal/index.php

Gurung R, N Pudasiani, S Sthapit, E Palikhey, A Adhikari and D Gauchan. 2020. Seed system of traditional crops in the mountains of Nepal. In: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Gurung R, SR Sthapit, D Gauchan, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: Ghanpokhara, Lamjung. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Joshi BK and D Gauchan. 2020. Geographical indication. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal; **pp**. 35-39.

Joshi BK, AK Acharya, D Gauchan, D Singh, KH Ghimire and BR Sthapit. 2017. Geographical indication: A tool for supporting on-farm conservation of crop landraces and for rural development. **In**: Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel; NAGRC, FDD, DoA and MoAD; Kathmandu, Nepal; **pp**. 50-62.

KC GK. 2006. An idea on organic agriculture system in Nepal. **In**: Proceedings of a First National Workshop on Organic Farming.12-14 June 2006 (Baishakh 28-30, 2063) Kirtipur, Kathmandu. Directorate of Agriculture Extension, Harihar Bhawan, Lalitpur; **pp**. 10-26.

Khanal RC. 2009. Climate change and organic agriculture. The Journal of Agriculture and Environment **10**: 100-110.

MoAD. 2013. National Standards for Organic Agriculture Production and Processing, revised version (2008) and Procedures for Export of Organic Certification Agro-products Cash Subsidy (2013). Ministry of Agricultural Development, Kathmandu, Nepal.

MoALD. 2019. A "Base Paper for Organic Agriculture Promotion Program 2076". Ministry of Agricultural and Livestock Development, Kathmandu, Nepal.

Moyer J. 2013. Perspective on Rodale Institute's farming systems trial. Crop Management. http://dx.doi:10.1094/CM-2013-0429-03-PS

Palikhey E, SR Sthapit, S Gautam, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2017. Baseline Survey Report: Hanku, Jumla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Parajuli A, A Subedi, AR Adhikari, SR Sthapit, BK Joshi, D Gauchan, B Bhandari and BR Sthapit. 2017. Baseline Survey Report: Chhipra, Humla. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Pokhara, Nepal: LI-BIRD, NARC and Bioversity International.

Pudasaini N, SR Sthapit, D Gauchan, B Bhandari, BK Joshi and BR Sthapit. 2016. Baseline Survey Report: Jungu, Dolakha. Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas. Nepal: LI-BIRD, NARC and Bioversity International

Pant KP. 2006. Policies and strategies of Nepal government to promote organic farming in the context of Nepal`s membership to WTO. **In**: Proceedings of a First National Workshop on Organic Farming.12-14 June 2006. Kathmandu. Directorate of Agriculture Extension, Harihar Bhawan, Lalitpur; **pp**. 170-178.

Pokhrel DM and KP Pant. 2009. Perspectives of organic agriculture and policy concerns in Nepal. The Journal of Agriculture and Environment **10**:89-99.

PRMS. 2014. Study on National Pesticide Consumption Statistics in Nepal. Pesticide Registration and Management Section (PRMS), Plant Protection Directorate, Department of Agriculture. Nepal. Final Report submitted by Mount Digit Technology, Lalitpur, Nepal.

Shrestha PL and K Pant. 2006. Agricultural extension in promoting organic farming in Nepal. **In**: Proceedings of a First National Workshop on Organic Farming.12-14 June 2006 (Baishakh 28-30, 2063) Kirtipur, Kathmandu. Directorate of Agriculture Extension, Harihar Bhawan, Lalitpur; **pp**. 35-42

Takeshima H, RP Adhikari, BD Kaphle, S Shivakoti and A Kumar. 2016. Determinants of chemical fertilizer use in Nepal. Insights based on price responsiveness and income effects. IFPRI Discussion Paper 01507, IFPRI, Washington DC.

The Himalayan Times. 2005. Honey exports to EU likely to resume. The Himalayan Times, October 25, 2005. https://thehimalayantimes.com/business/honey-exports-to-eu-likely-to-resume/

UNCTAD/UNEP. 2008. Best Practices for Organic Policy. What developing country Governments can do to promote the organic agriculture sector. UNEP-UNCTAD Capacity Building Task Force on Trade, Environment and Development. UNCTAD/DITC/TED/2007/3. United Nations, New York and Geneva. (www.unctad.org/trade_env)

UNEP. 2011. Organic Agriculture - A step towards the Green Economy in the Eastern Europe, Caucasus and Central Asia region Case studies from Armenia. Advance copy. Green economy. United Nation Environment Program (UNEP), Geneva.

||*

Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of the UNEP GEF Local Crop Project, Nepal; NAGRC, LI-BIRD, and the Alliance of Bioversity International and CIAT.

Value Chain Development and Mainstreaming of Traditional Crops for Nutrition Sensitive Agriculture in Nepal

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ABSTRACT

Traditional crops cultivated and consumed over generations are important components of agrobiodiversity that support dietary diversity, sustaining productivity and livelihoods of marginalized populations in Nepal. The paper outlines initiatives and progress made for value chain development and mainstreaming traditional nutrient-dense crops for nutrition sensitive agriculture by exploiting rich biodiversity in Nepal. Use of traditional crop biodiversity for nutrition sensitive value chain development can play positive role by taking into consideration not only how diverse nutrient-dense foods are produced but also how they are processed, distributed, marketed and consumed to supply nutritious food for household nutrition security. However, presently value chains of biodiversity of traditional crops are weak, fragmented and not properly connected among sub-components of production, processing, marketing and consumption system. Considering this, focus of biodiversity-based value chain development for mainstreaming nutrition sensitive agriculture is suggested and applied at the local and national level to improve their performance, efficiency and interlinkages. Progress made in mainstreaming good practices at the local and national level is being highlighted. Creating enabling policy for investment in research, education, extension and niche value chain development is essential to exploit rich biodiversity of traditional nutrient dense crops. Promotion of organic and ecofriendly production, marketing and certification system linking with geographic indication and fair trading is suggested for value chain upgrading and mainstreaming traditional nutrient dense crops in national policies, program and institutions.

Keywords: Biodiversity, biodiversity-based value chain, mainstreaming, nutrition security, traditional crops

INTRODUCTION

Nepal Himalayan mountain has a high degree of variations in topography, slope, aspect and altitude owing to diverse agro-ecological, socioeconomic and farming system resulting in high biodiversity in agriculture. Presently it harbours globally important crop biodiversity of traditional crops such as buckwheat, naked barley, different species of millets (finger millet, proso millet and foxtail millet), amaranth, beans and cold tolerant rice that have unique traits of cold and drought tolerance adapted to harsh risk prone marginal environments (UNEP GEF 2013, Upadhaya and Joshi 2003, Joshi et al 2020b). The intra-specific diversity of these crops is very high in Nepal mountains (Joshi et al 2018) as most of these mountain crops (eg naked barley, buckwheat) are either evolved or located at the center of diversity in Nepal Himalayas. Cold tolerant rice is grown in the highest altitude (3050 masl) in the world at Chhumchaur, Jumla, Nepal with its very high cold tolerance ability (Joshi et al 2020b). Buckwheat and naked barley are also grown in the highest elevation up to 4,500 msl in Nepal Himalaya (Upadhyay and Joshi 2003, Joshi 2008) providing food and livelihood security of marginalized people living in these harsh high mountain environments. These traditional crops are cultivated over millennia by farmers in the mountain regions and hence have helped to meet the local food security of marginalized communities in the face of changing climate (Gauchan et al 2019). These traditional crops currently account for 30-61% of the cultivated area in the many mountainous districts and to the extent of up to 61% of the cropped area in a high mountainous district of Humla (MoAD 2016). Hence, they are critical for food and nutrition of marginalized mountain communities despite, they account for small proportion of area (6%) at the national level (CSB 2012). As many of these crops are short duration (eg buckwheat, beans, foxtail and proso millet) they can escape drought and cold temperature and ensure food availability in shorter period in lean seasons where cultivation season is very short due to long cold winters in the Himalayan mountains. Furthermore, most of these crops (finger millet, proso millet, foxtail millet and amaranth) are photosynthetically more efficient (C4 crops), climate resilient and tolerant to various biotic (disease, pests) and abiotic stresses (cold, drought) and hence can be grown in harsh marginal lands with no or limited external inputs and water availability. Smallholder farmers are growing these food crops organically over generation using integrated mixed farming system, which have great potentials for improving national food and nutrition security

(Gauchan et al 2020a). These crops though neglected and underutilized at national level (Joshi et al 2019) are traditionally meeting multiple livelihood securities (food, fodder, nutrition, livelihood and ecological) of smallholder mountain farmers. Many of these crops have evolved and adapted in the risk-prone rainfed mountains and are gluten free, nutrient dense containing rich micronutrients, dietary fibers, rare amino acids, vitamins, and account for higher protein, calcium and iron as compared to major food staples such as rice, wheat and potato (DFTQC 2012, Joshi et al 2019, Joshi et al 2020c). **Table** 1 below provides comparative nutrient content of traditional crops in comparison to major food staples such as rice, wheat, maize and potato.

Table 1. Nutrient contents of traditional crops (per 100 gm) in comparison to major food staples

Crop	Protein (g)	Fat (g)	Carbo-hydrate (g)	Minerals (g)	Fiber (g)	Energy (Kcal)	Calcium(mg)	Phospho-rous (mg)	Iron (mg)
Foxtail millet	12.3	4.3	60.9	3.3	8.0	331	31	290	12.9
Proso millet	11.0	4.2	72.9	3.2	1.0	378	8	285	3.0
Amaranth grain	9.4	7.2	68.1	2.6	2.2	375	37	529	5.2
Barley	11.5	1.3	69.6	1.2	3.9	336	26	215	1.7
Naked barley flour	9.6	2.6	76.7	1.9	2.0	369	-	-	1.4
Finger millet	7.7	1.2	70.1	2.9	3.7	322	288	276	49.1
Buckwheat flour	6.1	1.3	69.2	3.1	7.8	313	-	-	5.6
Bean	24.9	1.3	60.1	3.2	1.4	347	60	433	4.4
Rice (milled)	6.8	0.5	78.2	0.6	0.2	345	10	160	0.7
Maize flour	9.2	3.9	72.1	1.2	1.6	360	20	256	2.4
Wheat flour	12.1	1.7	69.4	2.7	1.9	341	48	355	4.9
Potato	1.6	0.1	22.4	0.6	0.6	97	10	40	0.46

Source: DFTQC 2012.

In addition to the higher micronutrient and protein contents of the traditional crops, they are also considered tastier and healthier and therefore, consumers in urban market are recently paying price premium for food products derived from these crops as many of them are indigenous and produced organically in mountain agroecosystem. For instance, staple traditional meals (eg *Bhaat*, *Dhindo*) including modern recipes such as bread, porridge, snacks, pudding, sweets prepared from these nutrient rich traditional crops are recently becoming popular in urban areas in Nepal due to their perceived health and nutritional benefits. They are also considered hidden treasures and "Future Smart Food" considering their great value for nutrition, local adaptation, climate resilience and risk diversification (Li and Siddique 2018, Joshi et al 2019). In Nepal, the GEF UNEP Local Crop Project has named them as Himalayan Superfoods (www.himalayancrops.org). These traditional crops are intensively used by local mountain communities in many of the remote mountainous regions and contribute considerably to their food supply and nutrition. Therefore, these crops provide globally important gene pools for addressing chronic malnutrition and undernutrition in most impoverished areas of high mountain regions in the world. This paper aims to present initiatives and progress made in the development, mapping and mainstreaming of biodiversity-based value chain of traditional nutrient dense crops for nutrition sensitive agriculture and conservation and use of crop biodiversity.

RESEARCH METHODS

This study employs biodiversity-based value chain method for nutrition sensitive agriculture. Value chain of traditional mountain crops are studied from the perspectives of value chain development and mainstreaming from four representative high-altitude locations of Humla, Jumla, Lamjung and Dolakha districts. The research uses combination of methods using field surveys, consultation workshops, project meetings and literature review for mapping the value chains components and mainstreaming potential interventions for the nutrition sensitive agriculture. Specific focus has been given for mapping value chains into subcomponents of production, processing, marketing and consumption system and identify key constraints and bottlenecks in each of the component to address progress and initiatives made in mainstreaming good practices, technologies, diversity rich solutions and approaches. The information is supplemented with available data generated from field visits, consultation meetings and monitoring of value chain developments based on experiences of the project implementation from 2014 to 2019.

FINDINGS

Biodiversity-based value chains for nutrition sensitive agriculture

Value chains are a core element of the food systems, which influence both the supply and the demand of foods. A great potential exists to exploit nutrition value of traditional food crops through biodiversity-based value chain development in Nepal. Biodiversity-based value chain development of traditional food crops can play important role by taking into consideration not only how food is produced but also how it is processed, distributed, marketed and consumed, a process that is usually referred to as **'value chain'** (FAO 2017, Gelli et al 2015). Biodiversity-based value chain focuses on the use of the crop biodiversity to improve interlinkages and efficiency to promote nutrition value in each of the chain and activities in an interactive way (**Figure** 1).

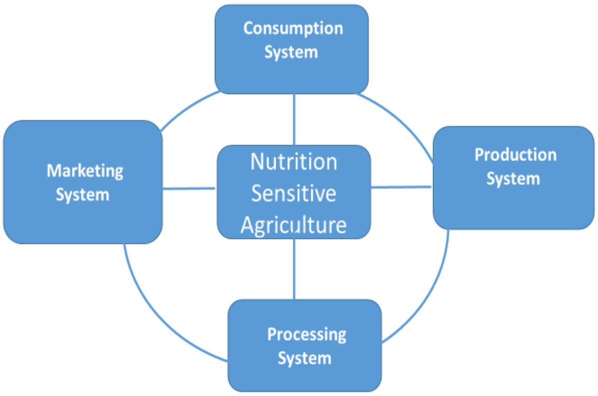

Figure 1. Components of biodiversity-based value chains for nutrition sensitive agriculture.

The biodiversity-based value chain emphasizes biodiversity not only in production system with diverse species and cultivars but also in the processing, marketing and consumption systems to promote dietary diversity and health of the populations. It aims to ensure household food and nutrition security by strengthening and linking all the sub-components of value chains which are outlined below.

1. Biodiversity in Production Systems: Diverse species and cultivars in the production at farm, landscape and ecosystem
2. Biodiversity in Processing System: Diverse species and varieties in processing
3. Biodiversity in Marketing Systems: Diverse species and cultivars in the markets
4. Biodiversity in Consumption Systems: Diversity in the diets derived from diverse species and varieties

There are different potential pathways to suggest in which value chain development and interventions can contribute to enhanced nutrition among the poor. One pathway is by enhancing access to, and consumption of foods that are naturally rich in micronutrients, such that overall dietary diversity increases (Maestre et al 2017). The second route through which increases in the supply and consumption of diverse nutrient-dense foods can be achieved is in the production and distribution of foods with increased nutritional value (Chen et al 2013). Value chain development of traditional diverse nutrient dense food crops can directly improve the livelihoods and nutrition security of poor farmers in marginal mountainous regions by increasing yields, managing marginal lands, decreasing losses during processing, adding value, improving market linkages and promoting consumption of nutrient rich foods among the households. Traditional food crops such as millets, barley, buckwheat, beans, amaranths fall on this group that are biodiverse and rich in micronutrients, dietary fibers and proteins (DFTQC 20112, Gauchan et al 2019). Adopting a biodiversity-based value chain approach allows for analyzing the roles and incentives of different actors along the chain, and to consider type of policy and regulatory framework that may be conducive for value chain to contribute to dietary diversity and quality for enhanced nutrition, including addressing cross cutting issues such as gender and climate change.

Mapping of value chain components and constraints

The mapping of value chain components and actors are assessed in the study sites with the specific sub-component, constraints and enabling policy factor (**Figure** 2). The assessment and mapping of value chains for traditional crops revealed the five major subcomponents constituting seed system, production, processing, marketing and consumption systems including policy system for creating enabling environment. Assessment revealed that presently the value chain of the traditional underutilized crops in each of the subcomponent is not well developed, poorly connected and occurs mostly in informal way. Seed system is poorly developed with low seed quality, low varietal diversity and their limited availability to farm households and farming communities. The production system is poor with limited variety adaptation, diversification and poor crop management. Processing system is very traditional with high women drudgery due to laborious manual processing, poor value addition and limited product diversification. Furthermore, value addition through processing and food recipe formulation, which is attractive to youth and women is limited.

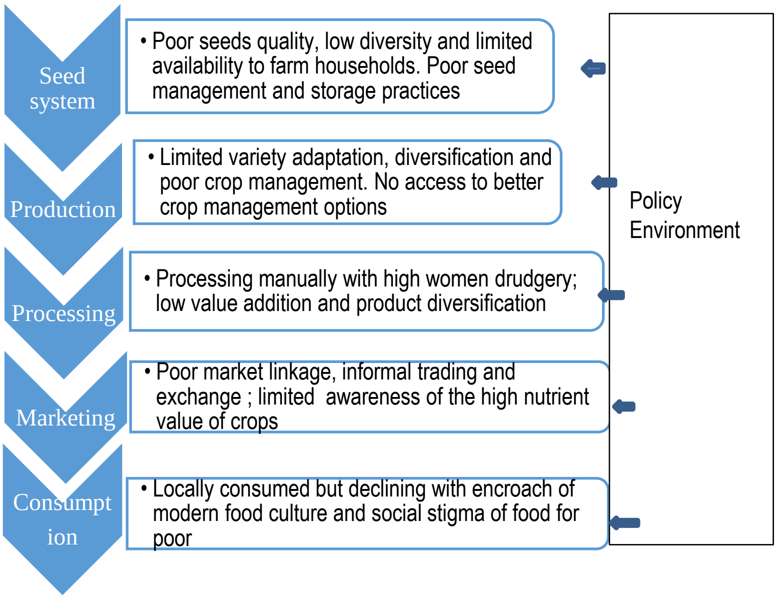

Figure 2. Mapping value chain of traditional mountain crops.

Marketing system is very weak with no proper market linkages and market information due to poor market awareness of the high nutrient and health value of the traditional mountain crops. With commercialization, urbanization and changes in food culture there is a loss of traditional knowledge on food preparation, marketing and use. Moreover, the technologies for food preparation are also not available and quality of products to be available for use are poor, with limited awareness of the value of the nutrient rich nature of the local crops, though a large quantity of finger millet, buckwheat and barley are being imported (TEPC 2018). Consumption of traditional food crops in the daily diets and food system of the rural households is deteriorating due to increasing encroachment of modern food culture and social stigma of these traditional foods. Hence, the flow of knowledge, products and information and interaction among chain actors from seed use to consumption is low and weak and the overall performance of the value chain is inefficient. The poor performance and inefficiency of the chain is due to poor enabling policy environments for supporting traditional nutrient dense crops among the chain subcomponents.

Process for mainstreaming value chains for nutrition sensitive agriculture

Mainstreaming of value chain of traditional mountain crops involves integration of good practices, knowledge, diversity rich solutions and technologies in each of the identified subcomponents of the chains including their scaling up at the subnational and national level. The value chain mainstreaming includes better management and improvement in different subcomponents of the chains covering seed system, production and processing, promotion (market and non-market means) and consumption systems that focuses on consumer's access and use of diversity of traditional diets (Figure 3).

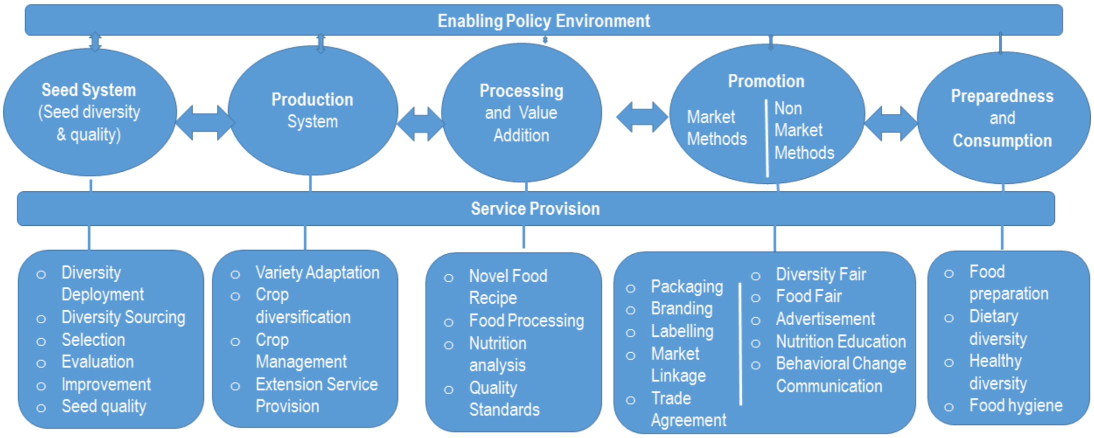

Figure 3. **Value chain upgrading and mainstreaming of traditional crops for nutrition sensitive agriculture.**

Mobilization and strengthening the capacity of actors in the value chains is one of the important aspects of the process. These actors range from seed conservers (custodian farmers and community seed banks) to producers, procurers, processors, value adders, distributors, traders and consumers. Special focus is in both the supply and demand side and their interface of the value chain interventions which are being addressed for upgrading the value chain of traditional underutilized crops. Enabling policy environment and service provisions play important role in the value chain pathways and performance of each of the chain. The process for mainstreaming and upgrading value chain for nutrition sensitive agriculture in the project sites and at the national level is outlined in the specific subcomponents of the chain given below.

Seed system

Project has mobilized and strengthened the capacity of farmers groups and cooperatives in four study sites in genetic resource management, Community Seed Banks (CSB) establishment, participatory crop improvement, and production and supply of quality and diverse seeds. Establishment and operationalization of community seed banks and farmers' Diversity Field Schools (DFS) are the important platform in four mountain project sites (Humla, Jumla, Lamjung and Dolakha) to conserve, exchange, share, manage and promote biodiversity of traditional nutrient dense crops. Community seed banks have conserved 232 landraces of 35 crops and also supplied 500 landraces to the National Genebank for safe long-term storage for future seed security of the mountain farmers. Key members and managers of the community seed banks are also part of the DFSs as they are closely interlinked for sourcing, deploying diversity and improving quality source production, maintenance and promotion (Pudasaini et al 2020). Project has sourced and deployed over 300 diverse genetic resources of traditional crops linking with the National Genebank, research centers and other seed suppliers were important approach to improve diversity of the seed system (Ghimire et al 2020). Participatory crop improvement approach focusing on participatory grass-roots breeding and Participatory Variety selection (PVS) including organization of site-specific agrobiodiversity fairs and participatory seed exchange events were also the key practices employed to improve and promote seed system of traditional nutrient-dense crops. Diversity assessment tools such as Four Cell Analysis (FCA) has been important to identify rare and unique crop genetic resources of traditional crops in the project sites (Joshi et al 2020a). Rescue and repatriation of native crop diversity of traditional crops using GIS and Climate Analogue Tool (CAT) in the project sites linking with the National Genebank and national research centers were carried out to conserve and restore unique diversity of traditional crop diversity (Joshi et al 2020a). To date about 20 MT of source seeds of 8 target crops are produced and distributed in the last 5 years which are accessing by about 20,000 smallholder farmers in Nepal. Community Biodiversity Management (CBM) trust fund has been an important approach employed to sustain community seed banks through self-financing model (Bhandari et al 2020a).

Production system

The producer (farmer) groups are strengthened and mobilized for the production of locally adapted crops and their cultivars. A total of 60 superior promising varieties of traditional nutrient-dense eight crops are identified, evaluated and made available for about 20,000 farmers for production management, local adaptation, crop diversification and promotion. Site-specific provisions are made from local project sites linking with local community-based organizations (community seed banks, cooperatives) and local extension services to facilitate regular provisions of agro-advisory services through participatory action research and development to provide diversity rich solutions, technologies, technical support and information (Gauchan et al 2019). These include participatory crop improvement methods (participatory grass-roots breeding, participatory variety selection) and participatory on-farm field trials covering diversity blocks, disease screening nurseries, agronomic and seed production demonstration field trials and deployment of diversity kits of superior genotypes. On-farm and on-station experiments for crop varietal mixture, organic seed production package and pollination and seed setting for ecosystem services were carried out to improve production system of the crops. Diversity field schools are regularly run to exchange knowledge, technologies and materials for the management of crops and cropping system focusing on biodiversity of the traditional nutrient dense crops. Disease and pest management including postharvest management were key activities included in the diversity field schools. A total of 120 DFS classes are run over the period of 2016-2019 in four project sites covering 100 farmers with 20-25 farmers from each project site. About 65% of the regular participants in DFS and CSB were women farmers (Pudasaini et al 2020).

Processing and value addition

For underutilized traditional crops, the role of processing and promotion systems is critical because the improved technologies for processing in the mountains is either limited or unavailable and marketing system is either weak or completely absent. Advancement, simplification, piloting and promotion of improved processing system, value addition and product diversification technologies, practices and approaches were key components employed to mainstream traditional nutrient dense crops. New electric processing machines for proso millet are designed and piloted and the electric finger millet threshers are promoted widely in the project sites and beyond for improving efficiency in processing and reducing drudgery of women and children (Bhandari et al 2020b). Several households have been operating these machines collectively which has helped to conserve and mainstream traditional crops in the local and national level. Introduction of women and youth friendly processing machines and training producers and traders in quality processing and value addition has been initiated which has shown great response and adoption from local farmers. Piloting of electric finger millet threshers in four study sites has shown that it is very effective in saving cost (3-4 times than manual processing), time and reducing women drudgery. In addition, development of technologies, practices and information for nutrition analysis, novel food recipe formulation, food preparation for adding value to local products and product diversification were also important activities employed by the project to mainstream nutrient value of the traditional crops (Ojha et al 2020).

Promotion system

Both market development (price, market agreement and market links) and non-market methods (seed and food fairs, nutrition awareness) are employed to raise demand and increase supply of their products. Promoting interlinkages among chain sub-components and strengthening the capacity of actors in the market and value chains are also the important aspects in the process. Special focus is in both the supply and demand side and their interface in value chain interventions. The project has facilitated linkage of local farmer cooperatives and CSB groups with local agro-entrepreneurs through tripartite agreement to market, process and promote final products, focusing on healthy, organic and nutritious wholesome foods and their food recipes linking with local retail shops, bakery, tourist hotels and markets (Gauchan et al 2019, 2020a). Linking seed (diversity fair) to food fair has been an important good practice for market promotion and raising nutrition value of traditional nutrient rich products (Gurung et al 2020). To promote seed value chain and also thereby product marketing, a model agreement has been developed for prior informed consent and seed business of local Dolakha beans with private Anamol Seed Company (Gauchan et al 2020a). Homestay group is also formed in Ghanpokhara, Lamjung linking with tourism to promote use of local food products such as foxtail millet pudding (*Kagunoko khir*) buckwheat and millet local products linking with local tourism. Value of nutrient rich traditional crops and their products are promoted and marketed linking with national organic shops, food fairs, organic exhibition and diversity fairs (Gauchan et al 2019). They are also being promoted through national and local level workshops, interaction meeting and news media.

Consumption system

Traditional crops suffer from social stigma of "food for poor and marginalized communities" (Padulosi et al 2019) hindering consumption of diverse available and affordable wholesome nutritious diets from these crops particularly among high income consumers. Therefore, promotion of nutrition and health value of these crops are important part of the framework. Promoting food preparation techniques with traditional way as well as through new food recipe formulation is critical to promote these food products among urban consumers and younger generation. The consumption of traditional crops is being promoted through proper packaging, labelling and branding as organic healthy wholesome nutrient rich foods from local products. For this, local entrepreneurs and bakery in Humla (Simikot) and home stay groups and traders in Lamjung (Ghanpokhara) were oriented to promote traditional food products. Training and orientation on food preparation of traditional crop products and promoting their nutrition value and use as the healthy diets have been important activities to promote consumption of nutrient rich traditional products. Programs supporting display of traditional food cuisines in local, regional and national food fairs has created awareness of the traditional food cuisine preparation and taste the wholesome healthy foods. Awareness creation for consumption of these foods through news media and education for local community groups and consumers has been important part of the process. Promoting market diversity of these crop products and supporting in technology development and promotion in processing and product diversification are also important to promote dietary diversity and ensure consumption of these products.

Enabling policy environment

Initiatives are being made at different steps of the value chain to create enabling policy environment to promote traditional underutilized crops. Policy review, analysis and advocacy for organic and ecofriendly production and marketing of nutrient rich traditional underutilized crops are on-going to develop and promote their market and value chains (Gauchan et al 2019). Initiatives are also on-going to simplify official release and registration process of farmers' varieties and improving policy environment for mainstreaming nutrition sensitive agriculture. Process for reviewing and revising agrobiodiversity bills (2018) to support legal provision for conservation, protection and ownership rights to farmers and communities is being done (Gauchan et al 2018). Community seed banks are strengthened and linked to national network for advocating local level legitimate institutions and platform for enhanced access and benefit sharing of agrobiodiversity materials (Gauchan et al 2020b). Awarding custodian farmers and developing mechanism and process for creating incentives for conservation and use of traditional crop biodiversity are good initiatives made in this direction (Gauchan et al 2020c). Several national and local level interactive workshops, consultation meetings and training programs were carried out to promote dialogue and engage in advocacy to facilitate registration and commercialization of farmers' varieties. In addition, special efforts are made for the provision of technical support and facilitation for revising seed regulatory framework and simplification of variety registration system suited for traditional crops and farmers' varieties for enhanced access and benefit sharing. Mechanisms for program level linkages and collaboration are being developed to mainstream and sustain project outcomes by linking with national and local government program. One of them is program linkage and partnership with "Indigenous Crop Promotion" program of Crop Development and Agrobiodiversity Conservation Center of the Department of Agriculture for mainstreaming project developed knowledge and good practices and promotion of traditional crops. Recently, the Government of Nepal, particularly Karnali province is making good initiatives to develop relevant policies and programs for developing and promoting value chains of traditional crops to ensure food and nutrition security of the marginalized mountain communities.

CONCLUSIONS AND POLICY IMPLICATIONS

The process of value chain analysis and interventions has provided ground base for developing and strengthening value chain of traditional crops for promoting nutrition sensitive agriculture in Nepal. The value chain has upgraded with better flow of diverse quality seeds, information, diversity rich solutions and products with improved interlinkages and efficiency in the subcomponents by adding value, improving market linkages and promoting consumption of nutrient-rich foods. Promoting interlinkages among chain subcomponents and strengthening the capacity of actors in the value chains are important aspects in the process. Focus of interventions are in sourcing, deploying and promoting diversity in seed system as well as the production of nutrient-rich traditional crops by making availability of locally adapted diverse varieties, quality seeds, production technologies and other diversity rich solutions. The piloting of electric finger millet thresher and, design and introduction of proso millet dehusker have provided options to reduce the drudgery of rural women and reduced cost of processing of labor intensive traditional crops in the remote mountainous region. The promotion of healthy organic foods with value addition, product diversification and linking with market chains (retail chains, urban food fairs, homestays and hotels) through local entrepreneurs is supporting to develop the niche value chain of underutilized crops. The value chain approach is thus useful for identifying pathways and opportunities to shape food systems to be more nutrition sensitive by intervening at different stages of the value chain (IFAD 2018).

The experience shows that value chain development offers great potential for exploiting biodiversity of traditional nutrient dense crops to improved nutrition outcomes and sustainable food system development. Traditional crops are indeed hidden treasures and provide globally important gene pools for nutrition and climate change adaptation for addressing chronic malnutrition and undernutrition of poor farmers and communities in most impoverished and vulnerable areas such as mid and far-western mountains in Nepal. Furthermore, promotion of intraspecific diversity of these crops will support conservation of agrobiodiversity for nutrition security, climate resilience and sustainable food system development as they are well adapted to diverse farming system, locally available and indigenous to Nepal mountains. Future efforts are needed to adopt social marketing and behavior change communication (BCC) for better marketing of local products linking with niche markets such as tourist hotels, homestays and hospitals including school meals and urban restaurant with traditional cuisines. Investment and interlinkages in research, education and extension of traditional crop biodiversity is critical in improving the efficiency and interlinkages in each chain of production, processing, marketing and consumption. Nutrition sensitive agriculture will require design of biodiversity-based value chain development and mainstreaming employing organic and ecofriendly production, marketing and certification system linking with geographic indication and fair trading. Most important is the creation of an enabling policy environment for investment in seed regulatory framework, subsidy, support and incentives for production, processing, marketing, value addition and consumption of locally sourced nutrient dense foods by exploiting rich biodiversity of traditional crops.

REFERENCES

Bhandari B, N Pudasaini, P Shrestha, KH Ghimire and D Gauchan. 2020a. Community biodiversity management (CBM) trust fund. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Bhandari G, BK Joshi, D Gauchan, D Bhandari and S Pant. 2020b. Simplifying the traditional processing system of minor millets. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Chen C, P Crawford, O Dary, A Drewnowski, H Namusoke, B Schneeman and M Towsend. 2013. Building Effective Nutrition Policy Demands a Strong, Evidence Base. Rome: FAO.

DFTQC. 2012. Food Composition Table for Nepal. National Nutrition Program, Department of Food Technology and Quality Control (DFTQC), Ministry of Agriculture Development. Kathmandu, Nepal.

FAO. 2017. Inclusive Value Chains for Sustainable Agriculture and Scaled up Food Security and Nutrition Outcomes. Background documents. Committee on World Food Security. 43rd Session "Making a difference in Food Security and Nutrition 17-21 October 2016, Rome.

Gauchan D, BK Joshi and B Bhandari, 2018. Farmers' rights and access and benefit sharing mechanisms in community seed banks in Nepal. **In**: Proceedings of 2nd National Workshop, Kathmandu (BK Joshi, P Shrestha, D Gauchan and R Vernooy, eds). NAGRC, LI-BIRD and Bioversity International; **pp**. 117-132. https://cgspace.cgiar.org/handle/10568/99141.

Gauchan D, B Bhandari, R Gurung, BK Joshi and D Jarvis. 2019. Value chain development of underutilized food crops for nutrition sensitive agriculture in the mountains of Nepal. **In**: Proceeding 5th International Agricultural Marketing Conference, Kathmandu, June 4-5, 2018. Nepal Agricultural Economic Society (NAES), Ministry of Agriculture and Livestock Development (MoALD), FAO, KISSAN-2, USAID, Nepal.

Gauchan, D, S. Pant, R, Gurung, N, Pudasaini, B, Bhandari, BK Joshi, KH, Ghimire and D, Jarvis, 2020a**.** Value Chain Development of Traditional Crops for Nutrition Sensitive Agriculture**. In:** Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gauchan, D., BK Joshi, B Bhandari, DS Shrestha, S Shrestha and D. Jarvis, 2020b. Community-based Mechanisms for Promoting Access and Benefit Sharing. **In**: Good Practices for Agrobiodiversity Management (Joshi BK, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gauchan D, BK Joshi, B Bhandari, N Pudasaini, R Gurung, KH Ghimire and KK Mishra. 2020c. Incentive Measures for Agrobiodiversity Conservation and Use**. In**: Good Practices for Agrobiodiversity Management (Joshi BK, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gelli A, C Hawkes, J Donovan, J Harris, SL Allen, A De Brauw, S Henson and D Ryckembusch. 2015. Value chains and nutrition: A framework to support the identification, design, and evaluation of interventions. IFPRI Discussion Paper o1413. CGIAR Research Program on Agriculture for Nutrition and Health. Washington, DC.

Ghimire KH, BK Joshi, R Gurung, N Pudasaini, D Gauchan, S Sthapit and D Jarvis. 2020. Diversifying the sourcing and deploying methods to enhance the crop diversity. **In**: Good Practices for Agrobiodiversity Management (BK Joshi,D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Gurung, R, N, Pudasaini, KH Ghimire and D Gauchan, 2020. "Food Fair": A mechanism for promoting traditional crops. **In:** Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

IFAD. 2018. Nutrition-sensitive value chains. A guide for project design, Volume I: Isabel de la Peña, IFAD and James Garrett, Bioversity International, Rome, Italy.

Joshi BK. 2008. Buckwheat genetic resources: Status and prospects in Nepal. Agric. Development Journal **5**:13-30. http://sites.google.com/site/jafgaubase/publication/journal-1

Joshi BK, SB Gurung, PM Mahat, B Bhandari, and D Gauchan. 2018. Intra-varietal diversity in landrace and modern variety of rice and buckwheat. The Journal of Agriculture and Development **19**:1-8. https://cgspace.cgiar.org/handle/10568/97576

Joshi BK, R Shrestha, IP Gautam, AP Poudel and TP Gotame. 2019. Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Joshi BK, KH Ghimire, B Bhandari, D Gauchan, R Gurung and N Pudasaini. 2020a. Red zoning and red listing. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Joshi BK, NA Gorkhali, N Pradhan, KH Ghimire, TP Gotame, P KC, RP Mainali, A Karkee and RB Paneru. 2020b. Agrobiodiversity and its conservation in Nepal. Journal of Nepal Agricultural Research Council **6**:14-33.

Joshi BK, P Ojha, D Gauchan, KH Ghimire, and HB KC. 2020c. Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. In: Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal (D Gauchan, BK Joshi, B Bhandari, HK Manandhar and DI Jarvis, eds). Tools and Research Results of UNEP GEF Local Crop Project, Nepal; NARC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu, Nepal (in this book).

Li X and KHM Siddique. 2018. Future Smart Food. Rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia, Bangkok; 216 pp.

Maestre M, N Poole and S Henson. 2017. Assessing food value chain pathways, linkages and impacts for better nutrition of vulnerable groups. Food Policy **68**:31-39.

MoAD, 2016. Statistical Information in Nepalese Agriculture. Ministry of Agricultural Development (MoAD), Kathmandu, Nepal.

Ojha P, R Karki, A Mishra, U Subedi and BK Joshi. 2020. Nutrition dense native crops and food recipes. **In**: Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International; Kathmandu, Nepal.

Padulosi S, P Roy and FJ Rosado. 2019. Supporting Nutrition Sensitive Agriculture through Neglected and Underutilized Species Operational Framework. Bioversity International and IFAD, Rome, Italy.

Pudasaini N, B Bhandari, R Gurung, S Shrestha and D Gauchan. 2020. Diversity field school (DFS) for managing agrobiodiversity. **In:** Good Practices for Agrobiodiversity Management (BK Joshi, D Gauchan, B Bhandari and D Jarvis, eds). NAGRC, LI-BIRD and Bioversity International, Kathmandu, Nepal.

UNEP GEF. 2013. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to buffer against Unpredictable Environmental Change in Nepal Himalayas. Project Document, United Nation Environment Program (UNEP), Global Environment Facility (GEF) and Bioversity International, Kathmandu, Nepal.

Upadhyay MP and BK Joshi. 2003. Plant Genetic Resources in SAARC Countries: Their Conservation and Management: Nepal Chapter. SAARC Agriculture Information Center; **pp**. 297-422.

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Glimpses of the Project Activities


Project recognition to women as custodian of agrobiodiversity

Display of newly developed proso millet thresher, Humla


Seed transactions in community seed bank, Chhipra, Humla

Seed production plot of local bean, Jungu, Dolakha

Project Steering Committee Members & Observers, 24 Feb 2020


Participants in National Sharing Workshop, 24 Feb 2020, KTM

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The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) delivers research-based solutions that harness agricultural biodiversity and sustainably transform food systems to improve people's lives in a climate crisis. The Alliance is part of CGIAR, a global research partnership for a food-secure future.

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Agrobiodiversity is the basis of our life.

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