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On-farm Status and Collection of Rice (*Oryza sativa* L.) Genetic Resources of Sikkim Himalayas

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Exploration trips were conducted to rice growing belts of Sikkim for collection and assessing on-farm status of rice landraces. Total of 52 traditional rice landraces collected along with record of passport data, features of cultivar and other aspects related to its cultivation and use. Inferences have been drawn based on observations on-field and interviews with local people regarding factors influencing rice diversity and reasons for their depletion. Probable strategies for conservation and maintenance of these landraces for their sustainable use have been discussed.

Key Words: Rice landraces, Genetic erosion, On-farm status, Northeastern India

Introduction

Half of the planet's population consumes rice (*Oryza sativa* L.) as staple food. It has played a key role in human nutrition and culture for the past 10,000 years. The human population is expected to reach 9.6 billion by 2050, suggesting the need to increase rice production which could feed the burgeoning human population. Rice is one of the most important food crops of India being grown in an area of 43.95 million ha with production and productivity of 106.54 million tonnes and 2239 kg/ha respectively, during 2013-14 (Anonymous, 2014a). Traditional rice cultivars are known for their valuable alleles which inevitably are the source material for development of new lines and tailoring the genotypes to withstand the impact of stresses as a result of climate change. Heterogeneous microclimate is a feature of hilly ecosystems where genetic variability and on-farm conservation of traditional varieties is a source of genes for rice improvement (Ikeda *et al.*, 1994; Rai 2007). Various workers have studied on-farm status of the rice diversity of Himalayan regions (Agnihotri and Palni, 2007; Mehta, 2010; Rana, 2009 and Sultan and Rao, 2013). The entire Northeastern region of India is known worldwide for its rice diversity (Singh *et al.*, 2006; Ngachan *et al.*, 2011; Choudhury *et al*., 2014). Sikkim is a small beautiful hill state of Northeastern India and is a biodiversity hotspot in Eastern Himalayan region. Rice is the most important staple food of the local people as inferred from the epiphet "Denzong" means the valley of rice. It is cultivated in 11.16 (000' ha) with production of 20.26 (000' tonnes) and productivity of 1815.74 kg/ha (Anonymous, 2014b). Scanty literature is available on rice germplasm of Sikkim (Kapoor *et al*., 2014; Roy *et al*., 2015). Rapid change in land use practices and land cover of various agro-ecosystems has resulted in loss of genetic resources. Due to limited conservation and information on the available rice germplasm in the state, it is prerogative to explore knowledge of the existing landraces and the factors affecting genetic diversity. This study was done with the objective to (a) explore the on-farm status of rice diversity (b) factors causing genetic erosion and (c) suggest conservation strategies for sustainable use.

Materials and Methods

Description of Study Area

Sikkim has a total geographical area of 7,096 sq Km which lies between latitudes 27º5'N to 20º9'N and longitudes 87º59'E to 88º56'E. Due to mountain barriers of Northeast India and the influence of Bay of Bengal, it is also one of the wettest regions in the Himalayan belt. The state receives an annual rainfall of 2000 mm to 4000 mm. July is the wettest month and rainfall is heavy and well distributed during the months of May to September. The hottest months are July and August and coldest are December and January. Sikkim's agro-ecological systems are divided in to lower hills consisting of tropical (300-500 m) and sub-tropical regions (500-

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1500 m), midhills (1500-2000 m), high hills (2000-5000 m) and very high hills (above 5000 m). The state is multiethnic. Eighty percent of the population lives in rural areas where agriculture plays a dominant role in the state economy with the total cultivable land by around 68,000 hectares (12% of the total geographical area). Moreover, the choice of crop is mostly consumption oriented and system of cultivation has established in low input, low risk, low yield technology because the primitive forms of agriculture is still most dominant.

Data and Sample Collection

Exploration trips were conducted during the year 2012 and 2013 to all the rice cultivated areas of Sikkim viz., East, West, North and South Sikkim (Figure 1). Samples were collected directly from the household along with passport data such as collector name, vernacular name of variety, latitude, longitude, elevation, common name, unique feature, frequency of occurrence, sampling method, habitat and other pertinent information collected for each sample. Seed sample of each accession were collected only once to avoid duplication. Validation of the cultivar identity was done by observing the seed colour and other morphological characters which have been authenticated by interviewing local farmers, extension functionaries and other local sources. Complete information on the rice landraces were collected by interviews with the farmers. We used structured unstructured and participatory approach for generating information related to its cultivation, past history and unique feature of the cultivar. Help of extension functionaries, village level workers and Panchayat heads were also taken for better interaction with the farmers and understanding of local knowledge. Due to the scattered inhabitation of the population in the remote locations and non-availability of data related to the approximate area under different rice cultivars, the inferences drawn are based on observations and interview with the local people from where the germplasm collected. Our data set contains information on the types of rice varieties the farmer grows, reasons for selection of the variety, unique features and limitations of the variety, common morphological traits in variety, maintenance of variety, seed management systems and probable reasons for depletion of genetic resources. The rice samples were collected from an elevation ranges from 475 m to 1758 masl.

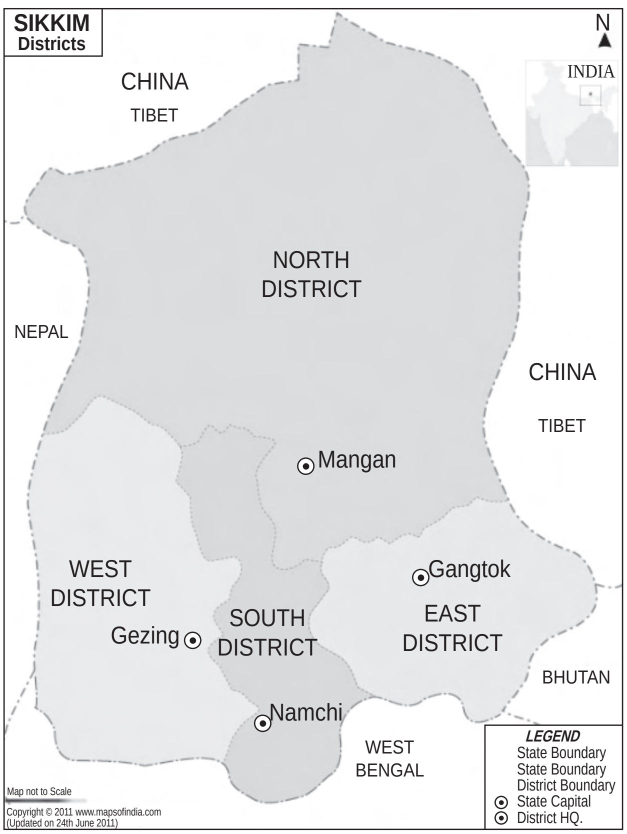

Fig. 1. Areas surveyed during rice germplasm collection in Sikkim

Results

Description of Rice Growing Belts of Sikkim

Rice is predominantly cultivated in terraces with narrow and serpentine fields (*Dhan Bari*) both in high altitude (*lekh* area) and low altitude areas (*owl* area). Rice is cultivated during *kharif* season (June-July) by traditional method. Rice cultivation is mainly done under rainfed lowland conditions where irrigation source is usually located at the topmost field from where water flows to another adjacent field with gravity flow. Seedlings are generally transplanted at 30 days after sowing but often delayed up to 45 days due to lack of good rainfall and scarcity of water in water streams (*Jhoras*) for impounding rice fields. For better seedling establishment, chopping top portion of seedlings is a common practice in late transplanting. Five to six seedlings are transplanted per hill. Rice monocropping is a common practice. The paddy fields are occupied with the crop up to November month owing to late maturity of cultivars. In upland rice cultivation direct seeding is done (only in small patches of North Sikkim) on slopy areas under slash and burn system. Transplanting at higher altitudes is done during second week of May to escape cold spells which arrive

Table 1. Rice genetic resources under cultivation in Sikkim Himalayas

S.No.	Cultivars and major cultivated areas	Frequency	Distribution	Farmers' criteria of nomenclature
North Sikkim				
1	Red Zomu	Rare	Localized	Morphological
2	Nepal Dhan	Rare	Localized	Place of origin
3	Zomu	Rare	Localized	Morphological
4	Takmaru	Rare	Localized	Morphological
5	Takmaru I	Rare	Localized	Morphological
6	Zokub	Rare	Localized	Morphological
7	Chini Dhan	Occasional	Localized	Place of origin
8	Taichung	Occasional	Localized	Morphological
9	Dharmali	Occasional	Localized	Morphological
10	Kalo Dhan	Occasional	Localized	Morphological
West Sikkim				
11	Pahelo Dalle	Rare	Localized	Morphological
12	Tauli	Rare	Localized	Morphological
13	Brihmphool	Rare	Localized	Morphological
14	Dudhey Juari	Rare	Localized	Morphological
15	Pusa Sugandha –II	Rare	Widespread	Govt. seed (Sarkari Dhan)
16	Sijali	Rare	Localized	Morphological
17	Bhangeri	Rare	Localized	Morphological
18	Ram Saree	Occasional	Localized	Morphological
19	Dhutraj	Occasional	Widespread	Morphological
20	Ram Bhog	Occasional	Localized	Morphological
21	Japani	Occasional	Localized	Morphological
22	Kalsati	Occasional	Widespread	Morphological
23	Lal Bacchi	Occasional	Widespread	Morphological
24	Musuli	Occasional	Widespread	Morphological
25	Katti	Frequent	Widespread	Morphological
26	Marsee	Frequent	Widespread	Morphological
27	Kataka	Frequent	Widespread	Morphological
28	Champey	Frequent	Widespread	Morphological
29	Doodh Kalam	Frequent	Widespread	Morphological
30	Kaley Bungay	Frequent	Localized	Morphological
31	Khimti	Frequent	Widespread	Morphological
32	Timburay	Frequent	Widespread	Morphological
South Sikkim				
33	Chari Nangrey	Occasional	Widespread	Morphological
34	Yeidehi	Occasional	Widespread	Morphological
East Sikkim				
35	Phool Patta	Rare	Localized	Morphological
36	Kalo Nunia	Occasional	Localized	Morphological
37	Zornali	Occasional	Widespread	Morphological
38	Chirakey	Occasional	Widespread	Morphological
39	Dhanase	Occasional	Localized	Morphological
All over Sikkim				
40	KRH-2	Occasional	Widespread	Govt. seed (Sarkari Dhan)
41	PD-10	Frequent	Widespread	Govt. seed (Sarkari Dhan)
42	VL-82	Frequent	Widespread	Govt. seed (Sarkari Dhan)
43	VL-85	Frequent	Widespread	Govt. seed (Sarkari Dhan)
44	Tabrey	Frequent	Widespread	Morphological
45	Jhapaka	Frequent	Widespread	Morphological
46	Attey	Abundant	Widespread	Morphological
47	Thulo Attey	Abundant	Widespread	Morphological
48	Sano Attey	Adundant	Widespread	Morphological
49	Krishna Bhog	Abundant	Widespread	Morphological
South and West Sikkim				
50	Chari Masini	Occasional	Widespread	Morphological
51	Anandhi	Frequent	Widespread	Morphological
52	Ram Zeera	Occasional	Widespread	Morphological
53	Sano Khamti	Frequent	Widespread	Morphological
East and South Sikkim				
54	Bael Butty	Rare	Localized	Morphological
55	Tulasi	Abundant	Widespread	Morphological
West and East Sikkim				
56	Phouryal	Frequent	Widespread	Morphological
East, South and West				
57	Khamti	Frequent	Widespread	Morphological

early in these areas. Majority of the rice fields are located below 1000 m asl (37.30%), 13.90% at 1000-1200 masl, 27.90% at 1200-1500 masl and 20.90% at a height more than 1500m asl. Direct seeded rice cultivation known as *Ghaiya Dhan* was a common practice in many rainfed areas of Sikkim, but this practice have been relinquished by farmers some 20-25 years back.

Genetic Variability

A total of 57 rice accessions were assembled which comprised of 52 local and 5 improved high yielding varieties (HYVs) (Table 1). Rice varieties presently under cultivation in Sikkim comprise of local landraces, obsolete varieties and improved high yielding varieties including hybrid. HYVs constitute around 12% of the total rice varieties grown. Varieties released for hilly areas like *VL-62* and *VL-85* were found under cultivation at higher altitude. Obsolete varieties like *Taichung* is still grown in small patches of North Sikkim.

Majority of the landraces were late maturing (150-175 days). Large variation observed in plant height which varied from 69.9 cm to 140 cm.

Kalsati bears long grains. About half of the total landraces were of short grain type. *Anandhi*, *Taichung* and *Timburey* are of broad grain type. Seeds of *Ramzeera* were smallest resembling to cumin. *Rambhog*, *Marsee*, *Kaley Bungey*, *Chirakey*, *Ramsaree*, *Musuli*, *Krishnabhog*, *Phool patta* and *Lal Bacchi* bear long panicles while *Tabrey, Taichung* and *Zornalli* bear short panicles. Maximum 1000 grain weight recorded in *Anandhi* (33.0 g).

Tulasi and *Champey Dhan* are aromatic and tasty rice mostly used as powdered rice, stuffed rice and Sathua. *Phouryal*, *Japani, Kalsati* and *Attey* for preparing *sale roti* (a local dish), *Dhanase* for chewda; *Tabrey*, *Brihmphool* and *Tulasi* for popped rice; *Krishnabhog, Kalonunia and Brihmphool* are known for their aroma and quality. Most popular rice cultivars are *Krishnabhog, Attey, Kalo nunia*, *Jhapaka*, *Tulasi*, *Champey* or *Champasari and Khamti*.

Attey is the most widely grown cultivar having two variants *Sano Attey* and *Thulo Attey* having small and bold type grains respectively. These are cultivated up to 1500 m asl. *Namfafzu*, *Dhanase*, *Takmaru, Dharmali, Juari Dhan, Red Zomu, Sirkey* are grown in high altitudes. *Sano* Attey is known for lodging resistance.

Table 2. Factors responsible for replacement and erosion of rice landraces in Sikkim Himalayas

Factors responsible	Percentage
Lack of manpower	40%
Area diversion to cash crops (Changes in cropping system)	25%
Lack of irrigation sources	10%
Low income	10%
High yielding varieties (HYVs)	10%
Low yield	5%

Awns were shorter in *Chirakey*, *Krishnabhog*, *Taichung* and *Takmaru* whereas highly conspicuous in *Brihmphool* and *Champey*.

The farmers' nomenclature of rice varieties is based on morphological characters and on location where these have been cultivated and found. Cultivars with small sized grains are annoted with *Sano* and *Masino* Dhan while long type with *Thulo* or *Lamo* Dhan. Cultivars like *Kaley Bungey*, *Kalo nunia* denotes black coloured lemma of the grain. *Tabrey* denotes the awns which are inseparable from rice grains. Largest variation in landraces recorded in West Sikkim.

Varietal mixture is one of the feature of local seed systems in Sikkim. Various varietal seed mixtures of *Brihmphool + Attey*, *Tulasi + Attey*, *Ananadhi + Attey* were found during seed collection.

Factors Affecting On-farm Rice Diversity and Varietal Choice

Agriculture in Sikkim is of subsistence type where rice is grown mostly for household consumption and some special rice varieties are grown for market purpose**.** Factors responsible for replacement and depletion of rice landraces in Sikkim are shown in Table 2**.** Agro ecology is the major factor affecting varietal preference. The important variable under it is the altitude and the irrigation availability. Irrigation sources were more in the low altitude areas where farmers cultivate two to three rice varieties. The high yielding varieties are mostly cultivated by progressive and socially well farmer who have access to modern technologies through Government interventions (state Agriculture departments and ICAR). The land availability with the farmer decides the number of landraces to be grown. Farmer cultivates rice varieties according to their needs as some rice varieties are grown primarily for processing and preparation of special products. Kalo nunia, a short grain aromatic type grown primarily for market purpose. Characters most preferred by the farmers in rice cultivar include tallness, high biomass yield, disease tolerance, grains with medium amylose content. Cultivar mixture has been observed to be a common feature in farmer's field. In one way it maintains the diversity in field and buffering against biotic and abiotic stresses. The seed supply system is basically local where the farmer retains the farm saved seed. The straw is also sold at a premium price in local market mostly used as fodder. A variety has both desirable and undesirable characters associated with it, thereby no single variety meets all the farmer needs (Bellan and Brush, 1994).

Erosion of Genetic Diversity

Based on interviews with the farmers and local heads probable reasons have been recorded for depletion of rice landraces, the inferences drawn are:

Rice cultivation in hills is a labour intensive operation. Shortage of agricultural laborers and manpower identified as the most important reason. Agricultural labourers have diverted to better employment opportunities due to which large stretches of rice fields remain uncultivated.

Lack of adequate irrigation sources for rice fields due to drying of temporary water streams *(Jhoras*) have decreased the area under the crop.

Due to small landholdings, farmers have diverted rice fields to cultivation of remunerative cash crops mainly vegetable production which are more profitable than paddy cultivation. Rice fields have been replaced by beans, cole crops, seasonal vegetables and other local vegetables which fetches premium price in market. Consistent poor yield of local cultivars adds to this crop shift.

Aromatic rice, which fetches premium price in the market has been slowly gaining acreage in the region. Farmers who were earlier cultivating 2-3 rice cultivars have now prefer aromatic rice due to its better market value and high demand.

In some areas introduction of HYVs have significantly decreased the area under local landraces. For example a drastic reduction in cultivable area of one of the high altitude rice cultivar *Phudungey* have been noticed and it could not be collected during our exploration. Similar trend recorded for *Brihmphool*, *Phouryal*, *Dharmali* and *Sirkey*. *Phouryal Dhan* was grown in lower Soreng belts of West Sikkim some years back but have been replaced by HYVs. Mehta *et al.* (2014) have reported replacement of approximately three dozens of traditional varieties from different agro-eco-niches by HYVs in Garhwal and Uttarakhand.

Sikkim has been declared as organic state where crops like ginger, large cardamom and buckwheat have gained prime importance due to their promotion under organic brand. Rice remained neglected in this regard. Factors like drought and erratic rainfall, poor yield of local varieties, availability of HYVs and change in crop sequences have also been reported by Mehta *et al.*, (2014) for erosion of traditional varieties. Rana *et al*. (2009) and Mehta *et al*. (2014) have studied the factors responsible for genetic erosion of the western Himalayan and Garhwal region of Uttarakhand respectively.

Discussion

Cultivation of genetically diverse landraces and mixture of different cultivars are most suitable cropping system in highly heterogeneous climatic and edaphic conditions of Himalayan region to averse risk of crop failure and maintain crop diversity on-farm. The reason seems most plausible for preponderance of traditional farming, is the remote and far flung inhabitation where input supply and technology flow is slow and strongly influenced by cultural and economic factors. Being a small state, having small cultivable area, variation in rice cultivars is noteworthy. These landraces are a result of conservation efforts and selection by the farmers and natural forces. Diversity in cultivated landraces depends mainly on farmer's choice being influenced by cultural and social factors. This demands for periodical exploration trips usually in period of 5 years for updating rice diversity status. There is ample scope for improvement of these landraces by employing pureline selection and hybridization with elite rice varieties. Improvement in post harvesting processing of quality rice along with better market linkages ensure remunerative prices to the farmers. The communities actively involved in diversity conservation should be compensated through allocation of funds to promote germplasm maintenance which can further be sustained through better seed storage facilities on-farm. In this era of Intellectual Property Rights (IPR) regime, new laws such as Protection of Plant Varieties and Farmers Rights Act (PPV&FRA act 2001), have been enforced in India to safeguard farmer's rights over their variety. Awareness regarding benefits of protecting rice varieties and benefit sharing accruing out of it will motivate farmers towards conservation. Adoption of high yielding rice varieties are must for increasing rice productivity in the region but adoption should be in line with the conservation of the replaced landraces. Maintenance and conservation efforts at community or village level would be more appropriate rather than at individual level, especially in hilly ecosystems. In this aspect, maintenance and updating of biodiversity registers have been initiated by Sikkim State Biodiversity Board (Department of Forests, Sikkim).

Categorization of landraces as widespread common, widespread rare, localized-common and localized rare based on pattern of occurrence in the region indicates their population structure (Khatiwada *et al.*, 2000). Rare localized cultivars viz., Red Zomu, Zokub, Nepal Dhan, Zomu, Takmaru, Pahelo dale, Tauli, Brihmphool, Dudhey Juari, Bael Buty, Sijali and Bhangeri needs immediate protection due to their small population size. Conservation *in-situ* ensures that the ongoing processes of evolution and adaptation of crops to their environments are maintained within farming systems and conservation at ecosystem level, species and genetic level. *Ex-situ* conservation efforts are equally important in these marginal areas due to their small population size, chances of erosion are more thereby maintaining seeds of accessions under controlled conditions and regenerating periodically will conserve it for long time. ICAR Research Complex for NEH Region, Sikkim Centre has initiated steps in this regard and have been maintaining and evaluating these landraces for different traits. For a biodiversity hotspot like Sikkim, it is important to have institution linkage for effective conservation plans by involving local, national or international bodies for effectively plan and execute conservation strategies. This will be successful only through greater participation of local leaders and farmers.

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