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ARTICLE

Evaluating Rice Biodiversity and Yields of Upland Rice Landraces Grown in Shifting Cultivation in Bandarban, Bangladesh

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ABSTRACT

Shifting cultivation, popularly known as *jhum*, is a dominant form of agriculture in the Chattogram Hill Tracts (CHT) of Bangladesh with upland rice being the major component of the system. The region is known for its rice biodiversity, which is under threat. This study was an attempt to explore the extent of rice biodiversity and variation in rice yields observing 81 randomly selected shifting cultivation plots from 26 dispersedly located mountainous villages in four sub-districts of Bandarban, one of three districts of the CHT. A total of 28 landraces of upland rice was grown in shifting cultivation. Highest number of landraces (16) was found in sub-district Thanchi. Three landraces most frequently observed were Gunda, Maemonsing and Sadabinni. Rice grain yield varied between 1.421 t ha-1 and 3.442 t ha-1 across landraces with the highest being recorded for Patobi. Landrace Dilon the lowest yield. Relative performance of landraces Kobrokbinni, Maemonsing, Monthon, Patobi and PD were superior to standard BRRI dhan83 and Gunda in relation to grain yield. Some of these landraces having wider adaptability may be released as varieties.

1. Introduction

Shifting cultivation, swidden culture, or popularly known as *jhum* cultivation in South and Southeast Asian countries is waning. In the wake of economic and social transformation, government regulations came down heavily transforming shifting cultivation into market oriented settled agriculture [1,2]. In Bangladesh, however, shifting cultivation still remains a dominant form of crop production in the sloping highlands of mountainous CHT [3,4]. The region, located in the southeast corner of Bangladesh, comprises three hill districts – Bandarban, Khagrachari and Rangamati. Geographically a part of Hindu Kush-Himalaya, the CHT is home to 12 ethnic communities. Unlike in the floodplains constituting a major segment of the country, the rugged, undulating mountainous lands of the CHT cover about 10% of the country's total landmass. However, only

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3.1% of the CHT land area is suitable for crop growing year-round while 74% represents hills and mountains with 2.72% sloping uplands[5]. High elevation hills and mountains are more and the proportion of arable land is less in Bandarban compared with other two hill districts of the CHT.

Two types of agricultural practices are prevalent in the CHT: plough agriculture or crop production in the valley lands using plowing as is being followed in plain lands, and traditional shifting cultivation in the sloping uplands in the hilly and mountainous areas. Shifting cultivation or *jhum* system is dominant and widely practiced for crop production in Bandarban [4,6]. In the shifting cultivation, farmers grow several crops together with rice being dominant under rainfed condition. Reliable statistics on area and production under *jhum* in the CHT are hard to get; but it is generally assumed that about 70,000 farmers practice *jhum* covering a minimum of 40,000 ha annually. The region is known for genetic diversity in rice [7].

Mountainous region comprising northern Myanmar, the CHT and northeasters Himalayan states of India might be center of diversity of Asian rice [8]. In uplands of the CHT farmers generally grow upland rice landraces in shifting cultivation that thrives depending on rainfall since irrigation cannot be provided in the sloping hilly lands. Many of the farmers prefer growing sticky and specialty rice cultivars. These upland rice landraces are traditionally grown in low-input, subsistence systems as is being practiced in similar environments in north-eastern India [9] and south-east Asian countries [10-12]. Invariably no farmer cultivates high yielding rice varieties in the shifting cultivation system.

Upland rice yield in the mountainous areas of the CHT is generally low [13,14] which may be attributed to culture type, land topography, rainfall characteristics and the varieties that farmers use [15]. Spatial differences in upland rice yields and varieties used have been reported [16]. Choudhury et al. [17] studied genetic structure and diversity of indigenous rice varieties grown in the Eastern Himalayan region of Northeast India. Atlin et al. [18] evaluated *indica* upland genotypes against traditional and improved tropical *japonica* upland varieties and elite *indica* high-yielding varieties (HYV) under high-fertility favorable upland conditions for characterizing the features of tested entries. Recently, Van Andel et al. [19] studied the diversity of rice genotypes used by the Guianas farmers in their traditional farming systems. Food insecurity is a major concern in such situations. Our earlier study conducted in Bandarban [14] also suggests that low yields of upland rice crop in shifting cultivation led to food insecurity of a greater segment of ethnic farmers. Mahmud et al. [20] suggested that improved management practices in rice replacing indigenous landraces with drought tolerant varieties might improve yield.

Yields of crops including upland rice are directly influenced by biophysical characteristics (www.ohchr.org/Documents/Issues/EPoverty/Lao/MilesKenneyLazarAnnex5.pdf) along with varietal differences [21]. Ran et al. [22] also showed that of all the factors associated with rice yield variation in mountainous terrain of southwest China, variety had more influence. In contrast, Sadimantara et al. [23](2018) reported fairly stable yields of local varieties of upland rice in Sulawesi of Indonesia. Roy et al. [24] evaluated 68 hill rice landraces of Northeast Indian states and categorized them in early and late maturing groups based on plant height, kernel length, kernel length-to-width ration, grain length, and grain length-to-width ratio. Similar information on genotypic variation in upland rice in Bangladesh is either scanty or unavailable, although Siddique et al. [25] studied the varietal differences of upland rice under lowland conditions and reported large variation in grain morphology. Some other authors reported low yields of indigenous rice in shifting cultivation or *jhum* in the CHT [14,26]; but work on yield variability and diversity of *jhum* rice has not been reported. This study was an attempt to evaluate the extent of rice biodiversity and yield potentials of upland rice genotypes grown in shifting cultivation in the uplands of Bandarban district in Bangladesh.

2. Materials and Methods

This on-farm study was conducted sampling shifting cultivators' plots, enumerating the rice landraces grown in shifting crops, and determining grain yields harvesting rice from the selected plots. Farmers established their shifting cultivation plots slashing forest, burning and clearing debris, and dibbling seeds following rains (April – May, 2019) without resorting to tillage on the mountainous uplands [27]. Once the shifting cultivation plots were established in the rugged terrains of hills and mountains, a team of Agrarian Research Foundation (AR) travelled through four upazila (sub-districts) of Bandarban district in June-July, 2019 to select farmers and their plots. Invariably all farmers in the selected locations planted upland rice in shifting cultivation plots, albeit the rice varieties and associated crops varied across locations. Visiting cropped areas and discussing with farmers, shifting cultivation plots were selected at random from 26 dispersedly located para (villages) of four upazila (sub-districts). A total of 81plots, each measuring

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one *kani* (0.16 ha) or more and the owner farmers thereof were selected for the study. Rice landraces planted in each plot were identified interviewing the owner farmers.

Rice crop attained maturity at different times beginning late-August through early October depending on planting time and landraces used by the farmers. Rice peduncle (panicle base) turning to yellow was taken as physiological maturity [28]. From each selected plot, three quadrants of rice, each quadrant measuring 1.0 m x 5.0 m, were sampled and harvested at maturity. Harvested rice of three quadrants of each plot was threshed and brought to ARF Office, Reicha (Bandarban) and sundried to a constant weight. Moisture content of dried rice samples was recorded, adjudged to 12% moisture content and converted to grain yield per ha. In view of unequal sample size in respect of number of farmers planted to each variety, variation in agronomic practices for growing rice across locations, and heterogeneity of experimental plots, analysis of variance could not be performed. However, rice grain yield data of each variety and location were subjected to descriptive statistical analysis wherever feasible.

Yield performance of landraces grown in shifting cultivation was compared with modern variety BRRI dhan83 and cultivar Gunda using Relative Performance (RP) as follows:

RP = (Grain yield of landraces)/grain yield of BRRI dhan83 or Gunda

Average yield data of BRRI dhan83 were taken from a trial recently conducted in nine upazila of the CHT [29] while the average grain yield of Gunda was taken from the present study. The performance of a genotype was considered satisfactory when RP was ≥ 1.

3. Results and Discussion

Selected farmers in 26 different locations (para) of four upazila in Bandarban district had planted 28 landraces of upland rice (Table 1). The cultivar most frequently observed was Gunda planted in eight locations followed by landraces Maemonsing and Sadabinni. The landrace Gunda was mostly concentrated in a few villages (para) in Rowangchari and Bandarban sadar upazila, while Sadabinni was dispersedly planted across four upazila of Bandarban district. Landrace Maemonsing was grown in mountains covering a cluster of three villages of three adjoining upazila- Rowangchari, Bandarban sadar and Ruma. Likewise, the production of cultivar Monthon was concentrated in high hills of Ruma and Thanchi upazila. Although few farmers planted landraces Batia, Chama, Chilikma, Dilon, Kanbui, Monbui, and Rongkui (Table 1), because of low yield potentials and growing food demand these landraces are progressively being extinct. Tribal people in the CHT prefer glutinous aromatic and specialty rice like Binni, Patobi, Rigui, Chilikma, a few farmers planted such genotypes because of their low yields.

Table 1 indicates that Thanchi upazila was the area for wider diversity of upland rice genotypes which was followed by Rowangchari. As many as 28 different landraces of upland rice were grown in association with other crops in *jhum* culture. Apart from commonly grown upland rice landraces, Thanchi farmers planted 12 more landraces compared with other three upazilas. In contrast, lesser numbers but more frequently observed landraces were grown in Bandarban sadar upazila. Sampled farmers in Thanchi upazila planted eight indigenous rice landraces which were mutually exclusive of the cultivars grown in other upazilas. Our findings indicate that Bandarban, located in the Indo-Burma border, still remains a biodiversity hotspot of a large number of indigenous rice landraces in the region. Valalsanga et al. [30] also recently indicated high genetic diversity of rice genetic resources in neighboring states of northeast India.

The number of farmers' plots we sampled in Ruma upazila was less compared with other three upazilas. The reason of fewer samplings in Ruma upazila was primarily due to distance from the district town (Bandarban) and *jhum* plots being located in relatively inaccessible areas. Such unequal sample size thus presented problem in running statistical analysis.

In the present study, a total of 81 plots of shifting cultivators were evaluated (Table 2). Eight farmers of five villages planted a fairly recently introduced cultivar Gunda in mid-range hills in Bandarban sadar and Rowanghchari upazila. The second most frequently used cultivars were Maemonsing and Sadabinni. Maemonsing was planted in high-range mountainous areas in three villages of Bandarban sadar, Rowangchari and Ruma upazila. Regardless of ranges of hills and mountains, Sadabinni genotype was widely grown throughout the four upazila in Bandarban district. Monthon genotype was also concentrated in the high range hills and mountains of Rowangchari and Thanchi upazila. Each of the two aromatic, glutinous rice varieties Kalobinni and Lal binni were planted by five farmers. Kalobinni was grown in high-range hills in southern part of Bandarban sadar while Lal binni occurred in low hills in Bandarban sadar, Rowangchari and Ruma upazila.

Table 1. Spatial distribution of rice varieties in four upazila of Bandarban district

Upazila (sub-dist)	Village (Para)	Genotypes planted
Rowangchari	Grokkhanpara	Reshamdhan
	Bijoypara	Lal binni
	Paglachara	Ranga dhan, Ranga binni, Sona dhan, Sadabinni
	Lulain para	Lendachikon
	Hanshama para	Gunda, Sadabinni
	Raja khamar	Gunda, Sadabinni
	Ramjadipara	Gunda
	Jaminipara	Cockrow, Maemonsing
Bandarban sadar	Lulai Headman para	Naisadhan
	Tungkhongpara	Gunda, PD, Rong Kui
	Parjatanpara	Kobrokbinni
	Tigerpara	Patobi
	Mrolongpara	Chilikma,Cockrow, Gunda,Kalobinni
	Ramripara	Chilikma,Kalobinni, Maemonsing, Sadabinni
Ruma	Thwingyapara	Lal binni
	Battolipara	Lal binni, Maemonsing, Monthon
	Royalpara	Sadabinni
Thanchi	Amtalipara	Dilongdhan, Monthon, Rongkui
	Bidyamoni Tripura para	Dilongdhan, DMP (Pahari), Monthon (Lomba Pahari)
	Boli bazaar Rai Mohan para	Batia
	Commanderpara	Chama
	Dakshinpara	Kopro
	ElmaraMarma para, Bolibazar	Rigui (s), Mongbui
	Komola bazaar Marma para	PD
	Kolaypara Jiban Nagar Hills	Sheshedhan, Sadabinni
	NiadariNicher para	Cockrow, Lal Binni, PD
	Sandakpara	Kanbui,Rongkui, Sona dhan

Scarcely occurring landraces like Batia, Chama, Chilikma, Dilon, DMP, Kanbui, Kopro, Mongpui, Rigui, Rongkui and Sheshe were planted in the mountains mostly in Thanchi. In Bandarban district, paddy is not traded in the market and rice is grown primarily for meeting household food requirements. It might be reasonably assumed that apart from ecological considerations, farmers' taste could be an important factor in selecting rice genotypes for cultivation in the study sites.

Table 2. Provenance of upland rice varieties planted in *jhum* in four upazila of Bandarban district

Variety/ landrace	Provenance	Farmers involved (No)
Batia	Boli bazaar Rai Mohan para, Thanchi	1
Chama	Commanderpara, Thanchi	2
Chilikma	Mrolongpara, Ramripara, Bandarban sadar	3
Cockrow	Hanshamapara, Rajakhamar, Ramjadipara (Rowangchari); Tungkhonpara, Mrolongpara (Bandarban sadar)	5
Dilon	Amtalipara, Bidyamoni Tripura para, Thanch	2
DMP (Pahari)	Bidyamoni Tripura para, Thanchi	1
Gunda	Hanshamapara, Rajakhamar, Ramjadipara (Rowangchari); Tungkhonpara, Mrolongpara (Bandarban sadar)	8
Kalobinni	Mrolongara, Ramripara (Bandarban sadar)	5
Kanbui	Sandakpara, Thanchi	2
Kobrokbinni	Parjatanpara, Bandarban	1
Kopro	Dakshinpara (Thanchi)	1
Lal binni	Bijoypara (Rowangchari); Thwingyapara(Bandarban); Bottolipara(Ruma)	5
Lendachikon	Lulain para, Rowangchari	1
Maemonsing	Jaminipara (Rowaqngchari); Ramripara (Bandarban sadar); Bottolipara(Ruma)	7
Mongbui	ElmaraMarma para, Bolibazar (Thanchi)	2
Monthon	Battolipara (Ruma), Amtolipara and Bidyamoni Tripura para (Thanchi)	6
Monthon (Lomba Pahari)	Bidyamoni Tripura para (Thanchi)	1
Naisadhan	Lulai Headman para (Bandarban sadar)	1
Patobi	Tigerpara (Bandarban sadar)	1
PD	Tungkhongpara (Bandarban sadar), Komola bazaar Marma para, Niadari Nich para (Thanchi)	5
Ranga binni	Paglachara (Rowangchari)	2
Ranga dhan	Paglachara (Rowangchari)	1
Reshamdhan	Gorokkhonpara (Rowangchari)	1
Rigui (scented)	Elmara Marma para, Bolibazar (Thanchi)	2
Rong Kui	Amtalipara, Sandakparaq (Thanchi)	4
Sadabinni	Paglachara, Hanshamapara, Raja Khamar (Rowangchari); Ramripara (Bandarban sadar); Royalpara(Ruma); Kolaypara Jiban Nagar Hills (Thanchi)	7
Sheshe	Kolaypara Jiban Nagar Hills, Thanchi	1
Sona dhan	Paglachara, Rowangchari; Sandakpara, Thanchi	3

Crops in shifting cultivation are grown in sloping uplands without land tillage and depending on natural rainfall. Onset and termination of rainy season determine the length of crop growing season. Seeds of upland rice are

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dibbled on dry land surface without tillage and the stand establishment relies heavily on rainfall. Rainfall records of Bandarban (Figure 1) suggest that rainfall received in April and May 2019 was favorable for a good stand establishment of rice and other component crops in the hills. Rainfall peaked in July-August when upland rice was in reproductive and grain-filling stages. It is reasonable to assume that rice experienced a good rainfall sufficient for supporting its growth. Our observations are in agreement with Saito et al. [31] who observed a close association between growing season rainfall and upland rice yield in Laos. Using 40 years' rainfall data Akinbile et al. [32] demonstrated that rice yield was positively related with rainfall in Nigeria. In a classification and regression tree analysis of a dataset, Bruelle et al. [33] showed rice yield was more affected by agro-environmental factors than management factors in Madagascar.

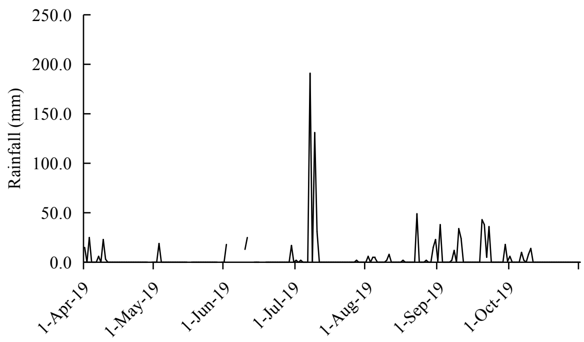

Figure 1. Rainfall pattern during experimental period, Bandarban, Bangladesh

Out of 28 landraces, each of 11 landraces had a single plot sample, and thus single plot sample yield data were used for these landraces. In other cases, the number of sample plots was unequal ranging from 2 to 8. Rice grain yields differed remarkably across landraces. Intra-genotypic difference in grain yield was also enormous (Table 3). Rice grain yield ranged between 1.421 t ha^{-1} and 3.442 t ha^{-1} showing a variation of over 142%. The highest yield was recorded for a long-grain, aromatic, glutinous rice genotype Patobi. A bold grain, non-aromatic glutinous cultivar Dilon produced the lowest grain yield (Figure 2). Fairly high and stable yield was obtained for genotypes Gunda (3.058 t ha^{-1}), Maemongsing (3.442 t ha^{-1}) and PD (3.106 t ha^{-1}). In view of relatively higher price and greater demand, yield of Sadabinni (2.880 t ha^{-1}) looks also reasonably good. The highest yield was obtained for the genotype Patobi; but because of sample size direct comparison of Patobi and other scarcely occurring landraces with those of frequently occurring landraces could not be made. Our results are in agreement with Zewdu et al. [34] who observed a wide variability in grain yield of upland rice which they attributed to differences in the test locations in Ethiopia and genotypic variations. Earlier, Van Keer et al. [35] also reported extensive variability in productivity of tropical japonica type glutinous upland rice varieties in an extensive research area in northern Thailand. Haryanto et al. [36] also reported wide variability in upland genotypes with significant genotype x environment interaction.

Table 3. Variations in grain yield of upland rice genotypes in Bandarban, Bangladesh

Variety/Landrace	Grain yield range (t ha^{-1})	Relative performance against	
		BRRI dhan83	Gunda
Batia	-	0.8152	0.6825
Chama	1.804 – 2.066	0.7047	0.5899
Chilikma	1.154 – 2.760	0.5805	0.4859
Cockrow	1.701 -2.812	0.8875	0.7430
Dilon	1.340 – 1.502	0.5551	0.4647
DMP (Pahari)	-	0.8156	0.6828
Gunda	2.190 -4.012	1.1945	1.0000
Kalobinni	0.752 – 2.047	0.6203	0.5193
Kanbui	1.765 – 2.120	0.7605	0.6367
Kobrokbinni	-	1.2363	1.0350
Kopro	-	0.8703	0.7286
Lal binni	1.340 -3.096	0.8563	0.7168
Lendachikon	-	0.8047	0.6736
Maemonsing	2.056 – 4.126	1.3324	1.1154
Mongbui	1.744 -2.910	0.8141	0.6815
Monthon	1.654 -3.763	1.2602	1.0549
Monthon (Lomba Pahari)	-	1.0000	0.8371
Naisadhan	-	0.6039	0.5056
Patobi	-	1.3445	1.1256
PD	2.098 – 3.888	1.2133	1.0157
Ranga binni		0.8387	0.7021
Ranga dhan	-	0.7578	0.6344
Reshamdhan	-	0.8156	0.6828
Rigui (scented)	1.405 -1.906	0.6465	0.5412
Rong Kui	1.614 – 3.487	0.9563	0.8005
Sadabinni	1.554 – 3.561	1.1250	0.9418
Sheshe	-	1.0000	0.8371
Sona dhan	1.326 – 2.066	0.6168	0.5164

- Data not available

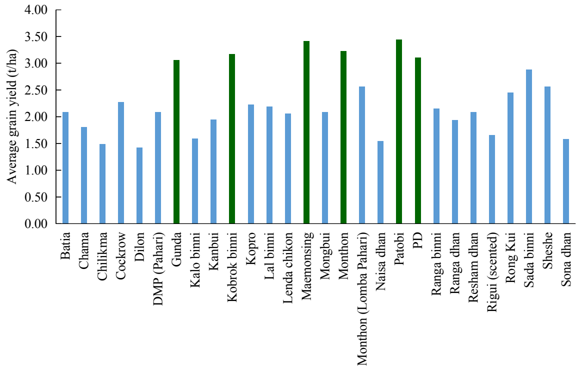

Figure 2. Average grain yield of upland rice genotypes in Bandarban, Bangladesh

Relative performances of local landraces in terms of grain yields were better or similar for Kobrokbinni, Maemonsing, Monthon, Patobi, and PD compared to BRRI dhan83 and Gunda (Table 3). These clearly indicate that some of the landraces are having potentiality of giving relatively higher grain yields at least in certain specific locations. Yield enhancement of these potential landraces could be tried providing improved agronomic management conditions. These may also be used as parent materials for developing drought tolerant high yielding varieties for adaptation in hilly areas.

All the upland rice landraces sampled in the study were grown in shifting cultivation. Frequency of occurrence of the landraces also differed a great deal across locations, except the genotype Sadabinni. However, all the landraces did not occur evenly throughout the study locations. Hence, analysis of spatial differences in rice grain yields or variety x location effect on yield variation was not attempted.

4. Conclusions

In the Chattogram Hill Tracts (CHT) in general, and Bandarban in particular, shifting cultivation has been the dominant upland rice ecosystems primarily due to land topography and socio-economic characteristics of the ethnic communities. Production of upland rice in shifting cultivation has been a key of food security for the resource-poor farmers in Bandarban. Most hill farmers prefer glutinous upland rice (like Binni, Patobi, Rigui etc.), but moderate yielding landraces are now gaining ground due to yield stability across locations and seasons. Farmers in Bandarban sadar, in the high range hills in southern Rowangchari and in Ruma prefer landraces Gunda, Maemonsingh and Monthon because of drought tolerance. In contrast, provenance of landraces like Cham, Chilikma, Kopro, Lenda chikon, Patobi, Resham dhan, Rigui and Sona dhan are in specific locations and probably have no wider adaptability or farmers' acceptability. For a long time, these location specific landraces endured harsh environment and adapted to local agro-climatic conditions with names that farmers selected and maintained to meet their social, economic, cultural and ecological needs [37]. Landraces are not considered in the public seed production and distribution system. In this study, the landraces showing potentiality of high yields across locations (for example, Gunda, Monthon) may be released as varieties for wider dissemination in the hilly areas.

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