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On-farm Diversity of Indigenous Rice (*Oryza Sativa* L.) Landraces in Border of Eastern Himalaya

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ABSTRACT

Eastern Himalaya is still unexplored in terms of the traditional rice, a reservoir of qualitative traits. The traditional rice is in serious threats from the social diversion and reduction in agricultural practices. The study was conducted to evaluate the status of the genetic resource of indigenous Rice (*Oryza sativa* L.) landraces and its diversity. Forty-one rice varieties were reported from diverse elevation exposures. Both univariate and multivariate statistical analysis had provided plenty of evidence on existence of polymorphism. Pearson's correlation of traits revealed1.8 % of the trait combinations correlated strongly (r = 0.68–1.00), 2.23 % correlated weakly ($r \leq 0.35$), while 5.69% correlated moderately (r = 0.36–0.67). The dendrogram obtained from Euclidian distance and UPGMA (Unweighted Pair Group Method with Arithmetic Mean), revealed three distinct clusters. The cluster analysis using the UPGMA and Euclidean distance revealed the range of genetic distance to be 10 to 757 and obtained three different clusters based on hierarchical clustering. The similarity was observed to be maximum between ACC47 and ACC48 and minimum between ACC46 and ACC49. Out of thirty independent principal components (PCs), top five PCs cumulatively account for 51.74% of the variance. Individual analysis of the factor loadings of the characters in the retained PCs showed that grain related traits have highest positive factor loadings in both PC1 (15.30% of the total variation) and PC2 (16.30% of the variance). While, the first two principal components (PC1 and PC2) cumulatively explained 27.61% of the total variance. The region has a potential for rice genetic resources, which can be a source of impending qualitative traits that can be useful for breeding purposes.

Keywords: Rice, agronomy, plant genetic resource, agrobiodiversity

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INTRODUCTION

The indigenous upland rice landraces of Arunachal Pradesh, withstanding wide range of agro-ecological constraints represents an incredible genetic inconsistency. It is extensively cultivated in slash-and-burn agriculture (locally called as *jhum kheti*) of this remote region (Wangpan et al., 2012). As the future productivity depends on the conservation of indigenous landraces, the importance of these germplasm cannot be ruled out *as a whole*.

The only way to ensure food security for future generations is to exploit the present day genetic diversity of different crop species and to identify the promising one for future breeding programs. Most importantly, a trait possessing high heritability along with high genetic advance would be valuable assets in such selection and breeding programs (Parikh et al., 2012). Even though India is one of the major centres of rice diversity, modern hybrid varieties of crops have caused a rapid erosion of the indigenous rice diversity, (Deb, 2006). Moreover, with the introduction of homogenous inbred lines, the indigenous landraces are disappearing fast and our information about them is still partial (Ray et al., 2013).

Conservation of rice still needs fundamental information about the reliable morphology. While, the qualitative characters are important for plant description and are mainly influenced by the consumer's preference, socioeconomic scenario and natural selection (Hien et al., 2007). Thus, characterization of crop germplasm through different morphological traits is critical for the assessment of its genetic potential. Phenotyping is an important activity to evaluate the first-hand information on the utilization of germplasm fundamental in order to provide necessary information for plant breeding programs (Rabara et al., 2014).

As most of the indigenous rice thrive naturally in uplands, the evidence about them is still inadequate. Therefore, to fill this gap, the untapped upland rice cultivars of this region were characterized and evaluated using morphometric markers. This technique is a low-level yet powerful taxonomic tool and thus is useful for the preliminary depiction of cultivars prior to their characterization via more vigorous marker technologies (Zapico et al., 2010).

Owing to its rich and diversified distribution, the traditional rice landraces of this region has tremendous potential in the context of research and allied activities. The characterization and conservation of these rice accessions are inevitable not only for posterity, but also for the deployment in searching for improved genes with improved characters, including glutinous or aromatic grains, high yielding in stress condition, tolerant to drought and resistance to pest etc. Thus, there is an urgent need to explore the available germplasm and conserve these indigenous landraces before it is lost in time. Besides, the present study will also be useful for germplasm managers in planning for future germplasm acquisitions of the region.

MATERIALS AND METHODS

Study Area

Tirap and Longding districts of Arunachal Himalaya lies between the 26º 38' N and 27º 47' N latitudes and 96º 16' E and 95º 40' E longitudes. Tirap district is bounded by Myanmar towards the South, Changlang District of Arunachal Pradesh towards the East, Dibrugarh District of Assam in the North and Longding district towards the West. The district derived its name from the "Tirap River" and is covered with high hills and deep gorges. The Longding district was carved out from Tirap district is inhabited by Nocte and Tutsa tribes with many sub-tribes; whereas, Longding district is the land of the lone Wancho tribe. Occupying a distinct geographical area, each of these tribes has their own rich social norms, customs, beliefs and practices. These tribes are mostly agrarian, earning their livelihood through traditional farming where rice form the principal food crop.

Field Survey and Data Accumulation

The field visit was carried out during year 2013 to 2015 in 24 rural hamlets for the collection of rice samples and ethnobotanic field data with the help of standard questionnaires (Jain & Mudgal, 1999, Tangjang et al., 2011). The experimental data were based on measurement of the 10 rice plant randomly chosen in the fields for each landraces. The characteristics of the mature rice plant were recorded shortly after the anthesis prior to harvest. The rice landraces were subjected to characterization using both quantitative and qualitative morphogenetic traits of different rice varieties (Zapico et al., 2010). Data were compiled for twelve qualitative and twenty quantitative traits following NBPGR descriptor (Mahajan et al., 2000). The mean values of the data obtained from the survey of three consecutive years were used for the analysis. The size of the rice grains was classified following Cruz and Khush (2000). The yield component, however, was estimated following the equation of Yoshida (1981).

Data Analysis

As described by Hutchenson (1970), using the phenotypic frequencies, the Shannon-Weaver diversity index was calculated. To keep Shannon-Weaver diversity index between 0 and 1 the formula suggested by Hennink and Zeven (1991) was followed. An arbitrary scale was also adapted using PAST software, to classify the computed indices as maximum (H'= 1.00), high (H'= 0.76–0.99), moderate (H' = 0.46–0.75) and low diversity (0.01–0.45) (Jamago and Cortes 2012). A correlation (Pearson) heat map was constructed to visualize correlation between the traits that had weak ($r \leq 0.35$), moderate ($r = 0.36–0.67$) and strong ($r = 0.68–1.00$) correlations (Taylor, 1990). Multivariate statistical analysis was performed using Principal Component Analysis (PCA) and Cluster Analysis (CA). PCA and CA were assessed using XLSTAT (version-2014) and STATISTICA (version-8.0) software respectively.

RESULTS AND DISCUSSION

The present study recorded a total of 41 indigenous upland rice varieties with accession codes ranged from ACC01-ACC54 (Table 1) from the jhum fields. These varieties were subjected to score and a measurement of 12 qualitative and 20 quantitative morpho-agronomic traits.

Table 1
Vernacular name and accessions code of indigenous upland rice varieties of Eastern Himalayas

Sl No.	Local Name	Accessions Code	Sl No.	Local Name	Accessions Code
1	Aratlisa	ACC01	22	Patam	ACC32
2	Aratratnu	ACC02	23	Phanu	ACC33
3	Chahchia	ACC04	24	Phihsa	ACC34
4	Chahchiang	ACC05	25	Sahtho	ACC35
5	Chhaggo	ACC06	26	Sahkhee	ACC37
6	Chahlo	ACC07	27	Sahzaan	ACC38
7	Chahmai	ACC08	28	Saulingnu	ACC39
8	Chahnu	ACC09	29	Semoi-K	ACC40
9	Chahsa	ACC10	30	Semoi-L	ACC41
10	Chahyong	ACC13	31	Senai	ACC42
11	Chahzaa	ACC14	32	Taigo	ACC43
12	Champo	ACC17	33	Toinu	ACC45
13	Honai	ACC18	34	Toisa	ACC46
14	Lailo	ACC22	35	Zaamkhee	ACC47
15	Longri	ACC23	36	Zaamlo	ACC48
16	Lozon	ACC24	37	Zaamnu	ACC49
17	Maichong	ACC25	38	Zaamsa	ACC50
18	Maijah	ACC26	39	Zaamzan	ACC51
19	Maujah	ACC27	40	Zungnu	ACC53
20	Aaosah	ACC30	41	Langmai	ACC54
21	Osusah	ACC31			

Quantitative Trait Evaluation

Significant ranges of variations for quantitative agro-morphological traits were recorded among the indigenous landraces (Table 2). Maximum plant height was observed in ACC41 (191 cm); whereas, minimum plant height was recorded in ACC04 (134.098 cm). Plant height is a complex character, controlled by the internodes (Cheema et al., 1987). Interestingly, the accessions having a short plant height may improve their resistance against lodging; thus, reducing the losses of yield (Ookawa et al., 2010).

Accession ACC23 displayed maximum flag leaf length with an average of 75.7 cm; whereas, ACC06 displayed a minimum of 43.0 cm. ACC49 with 2.82 cm and ACC04 with 1.78 cm displayed maximum and minimum leaf width respectively. Flag leaf plays an important role in grain filling, while top two leaves produce 80% of the stored carbohydrate in the grains (Gladun and Karpov 1993). Additionally, it is the major source of phloem-delivered photo-assimilates during the grain-filling stage and important in cereal breeding for improved lodging resistance (Biswal and Kohli 2013).

Culm length, ranged from 24.2 cm (ACC41) to 41.9 cm (ACC27); while, the culm diameter among the accessions ranged from minimum 0.36 cm (ACC47) to maximum 0.8 cm (ACC38). The score of culm diameter was observed to be higher as reported by Rabra et al., (2014). On the other hand, culm numberranged from 4.00 (ACC04) to 6.00 (ACC25, ACC27, ACC28, ACC32, ACC35, ACC39, ACC41). Most of the accessions with maximum number of culms were observed with the maximum height in comparison to their counterparts. Likewise, ACC41 with maximum number of culms was observed to be the tallest of all. The rice varieties' having large culm have long spikes and contains highest number of grains per panicle (Wu et al., 2011). The rice accession ACC27 with larger culm (culm length and diameter) in comparison to ACC41 was scored higher for yield attributes (spikelet per panicle and filled spikelet per panicles).

ACC08 had maximum number of tillers (13.6) as well as total number of filled tillers (10.6); whereas, ACC06 was recorded with minimum number of total tiller (5.2) as well as filled tiller (4.8). Number of spikelet per panicle ranged from 192.20 (ACC45) to 349.60 (ACC34). ACC26 with an average score of 327.2 and ACC45 with 174.6 were observed with maximum and minimum number of filled spikelet per panicle respectively. The score of tillers per plant was comparatively low, which was one of the criteria used by IRRI rice breeders in selecting donor parents to be used in developing new plant types (NPTs) of rice (Peng et al., 1994). The range of the grain length among the rice genotypes varied from 0.561 cm (ACC10) to 0.899 cm (ACC02). Grain width among the rice genotypes varied from 0.257 cm (ACC39) to 0.368 cm (ACC49). The sterile lemma length among the rice genotypes ranged from 0.132 cm (ACC17) to 0.281 cm (ACC23). All the accessions were recorded with sterile lemma of maximum length, which contributes to the total photosynthates stored in the grains (Chakravorty et al., 2013). Accession ACC51 was scored with maximum 1000 grain weight of 28.69 grams, while ACC04 was scored a minimum of 13.63 grams. Li et al., (2010) proposed the grain weight to be one of the most important characters enhancing polymorphism in rice genotypes. Accession ACC46 was recorded with minimum grain yield of 346.06 kg ha^{-1}, while accession ACC49 was recorded with a maximum grain yield of 1102.55

kg ha^{-1}. Peng et al., (1993) attributed the heightening in grain yield to the favorable effects of improved leaf N concentration, photosynthetic rate of flag leaves and increased filled grain percentage.

Plant height, leaf width, culm number, grain width and kernel thickness were the only character with CV values less than 10 % (Table 2). Thus, a high CV score of total tiller (20.44), productive tiller (20.30), kernel length and breadth ratio (22.71 %) and grain yield (31.34 %) per plant, indicates that the selection based on these characters is expected to be more effective.

Table 2
Descriptive statistics for 20 quantitative agro-morphological traits of 41 indigenous rice of Eastern Himalayas

Variables	Range	Mean	Std. deviation	CV (%)
PH	13.498 to 19.100 cm	164.28	12.38	7.54
LL	4.30 to 7.570 cm	61.42	8.09	13.17
LW	0.178 to 0.2.82 cm	2.28	0.17	7.56
CL	2.420 to 4.190 cm	31.39	3.22	10.26
CN	4.20 to 6.00	5.19	0.47	9.02
CD	0.036 to 0.08 cm	0.49	0.08	17.23
TT	5.20 to 13.60	7.94	1.62	20.44
FT	4.80 to 10.60	6.75	1.37	20.30
TFS	174.60 to 327.20	271.43	30.99	11.42
TUS	14.00 to 29.00	21.17	3.62	17.11
SN/P	192.20 to 349.60	292.60	31.92	10.91
GL	0.561 to 0.899 cm	6.82	0.84	12.35
GW	0.257 to 0.368 cm	3.12	0.29	9.38
SLL	0.132 to 0.281 cm	2.12	0.30	13.91
KL	0.334 to 0.638 cm	4.69	0.66	14.13
KW	0.208 to 0.488 cm	2.71	0.45	16.61
KT	0.142 to 0.216 cm	1.82	0.17	9.42
KL/KW	0.100 to 0.279	1.78	0.40	22.71
1000 GW	13.63 to 28.69 g	19.96	3.70	18.53
Y/H	346.06 to 1102.55 kg	642.51	201.35	31.34

Note: PH= Plant height; LL= Leaf length; LW= Leaf width; CL= Culm length; CN=Culm number; CD= Culm diameter; TT= Total tiller; FT= Filled Tiller; TFS= Total filled spikelet; TUS= Total unfilled spikelet; SN/P= Spikelet number per panicle; GL= Grain length; GW= Grain width; SLL= Sterile lemma length; KL= Kernel length; KW= Kernel width; KT= Kernel thickness; KL/KW= ratio of kernel length and kernel width; 1000 GW= 1000 Grain weight; Y/H= Yield per hectare

Qualitative Trait Evaluation

Rice genotypes were characterized for important leaf traits at late vegetative and flowering stages. Of the total, 70.73% (29 accessions) were recorded with light green, 2.44% (2 accessions) with medium green and 26.83% (11 accessions) with the dark green intensity of green color. The divergence was also observed among the accessions for basal leaf sheath color; thirty-four (82.93%) rice accessions showed green color, six (14.63%) accessions were purple lines, whereas only one (2.44%) with purple color. The leaf pubescence of leaf blade were scored as strong (36.59%), medium (53.66%) and weak (9.76%). Interestingly, the divergence was recorded nil for the flag leaf angle. The intensity of leaf color correlates with the nitrogen concentration (Nachimuthu et al., 2007), which finally affect the yield.

Two types of panicle curvature of main axis were observed among varieties, i.e. straight (12.20%) and semi-straight (87.80%). A total of 80.49% was recorded with well exerted panicle, whereas 19.51% of them were recorded with mostly exerted panicles. The panicle secondary branching was observed as strong (87.80%) or clustered (12.20%). Moreover, the accessions were observed with erect (12.20%) or semi erect (63.41%) attitudes of panicle branching.

Accessions ACC09 and ACC47 were recorded with dark brown decorticated grain color, while remaining accessions have white pericarp. The grains, with red and black pericarp colors have a higher concentration of phenolic compounds (Zhou et al., 2004). The maximum level of variation was recorded against lemma and palea color of rice grains, such as straw (75.61%), brown (17.07%), reddish to light purple (2.44%), purple furrow on straw (2.44%) and black color (2.44%).

Presence of awn was reported only from four rice accessions (ACC8, ACC9 ACC22 and ACC30). Three different awn colors were observed viz., ACC22 and ACC30 with black (25%), ACC8 with brown (50%) and ACC9 with yellowish white (25%). The long awn protects the grains from pilfering by birds and animal (Rabara et al 2014). Besides, short awns allow easier harvesting (Hu et al., 2011). Variations were also found among the studied rice accessions for grain (kernel) size and shape. Grains were characterized as very long (17%), medium (49%) and long (34%). Except accessions ACC01, ACC02, ACC23 and ACC37, which were observed with medium-slender shape, remaining accessions, were recorded to be short-bold in shape

Qualitative and Quantitative Traits Diversity

Diversity index (H’), which accounts for the abundance and evenness of the agro-morphological traits revealed a high degree of diversity among the landraces (Table 3). The existence of high variability, as shown by diversity values recorded indicates that the diversity among the populations is due to variation in traits.

Table 3
Shannon-Weaver indices (H') for 32 agro-morphological traits of 41 indigenous rice of Eastern Himalayas.

Agronomic traits	Code	Evenness_e^H/S	H'	Remark
Leaf pubescence	PB	0.9812	0.99	High
Basal leaf sheath colour	BS	0.869	0.96	High
Leaf intensity of green colour	LG	0.8669	0.96	High
Panicle curvature	PC	0.9823	1.00	Maximum
Awning	AW	1	0.37	Low
Awn colour	AC	0.7844	0.31	Low
Flag leaf angle	FA	1	1.00	Maximum
Panicle exertion	PE	0.9892	1.00	Maximum
Panicle secondary branching	PS	0.9004	0.97	High
Panicle attitude of branching	PA	0.9645	0.99	High
Decorticated grain colour	DG	0.948	0.99	High
Grain lemma and palea	LP	0.7917	0.94	High
Plant height	PH	0.9972	0.999	High
Leaf length	LL	0.9914	0.998	High
Leaf width	LW	0.9972	0.999	High
Culm length	CL	0.9949	0.998	High
Culm number	CN	0.9961	0.999	High
Culm diameter	CD	0.9865	0.996	High
Total tiller	TT	0.9805	0.995	High
Filled tiller	FT	0.9806	0.995	High
Total filled spikelet	TFS	0.9935	0.998	High
Total unfilled spikelet	TUS	0.9857	0.996	High
Spikelet number per panicle	SN/P	0.994	0.998	High
Grain length	GL	0.9928	0.998	High
Grain width	GW	0.9957	0.999	High
Sterile lemma length	SLL	0.9902	0.997	High
Kernel length	KL	0.9904	0.997	High
Total tiller	TT	0.9805	0.995	High
Filled tiller	FT	0.9806	0.995	High
Total filled spikelet	TFS	0.9935	0.998	High
Total unfilled spikelet	TUS	0.9857	0.996	High
Spikelet number per panicle	SN/P	0.994	0.998	High
Grain length	GL	0.9928	0.998	High
Grain width	GW	0.9957	0.999	High
Sterile lemma length	SLL	0.9902	0.997	High
Kernel length	KL	0.9904	0.997	High
Kernel width	KW	0.988	0.997	High
Kernel thickness	KT	0.9957	0.999	High

Table 3 *(continue)*

Agronomic traits	Code	Evenness_e^H/S	H’	Remark
Kernel length and width ratio	KL/KW	0.9761	0.993	High
1000 grain weight	1000 GW	0.9836	0.996	High
Yield per hectare	Y/H	0.9539	0.987	High

Both qualitative and quantitative traits have a diversity index by an average of 0.873 and 0.997 respectively, displaying the quantitative agronomic traits to be comparatively more abundant and dispersed. The traits such as flag leaf angle, panicle related descriptors such as curvature and exertion with maximum diversity were dispersed equitably as compare to other characters. Whereas, the awn related trait had the lowest H’ value (0.31 and 0.37). The flag leaf angle trait was observed invariants and have displayed a maximum diversity as well as the evenness (E=1 and H’=1). Ranging between 0.94-0.99, seven (58.33%) qualitative traits scored high diversity with an average index of 0.97. Two of these traits were panicle-related, three were leaf related and the rest were grain related. Most of the quantitative traits, however, had moderate (5 traits) to high (12 traits) diversity indices. Ranged from 0.993 to 0.999, all the quantitative traits showed a high diversity with an average H’ score of 0.997. Minimum diversity and evenness, however, was recorded with kernel length and width ratio, while the plant height displayed highest diversity and evenness.

Correlations among the Agro-Morphological Traits

Only 1.8 % of the trait combinations were correlated strongly (r = 0.68–1.00), 2.23% were weakly ($r \leq 0.35$) correlated, while 5.69% were moderately (r = 0.36–0.67) correlated (Figure 1). The analyses showed a moderate correlation between the plant height and culm number. This indicates the importance of culm number in the heightening of the plant. Similarly, Chakravorty et al. (2013) observed correlation of plant height with the culm diameter and culm number. Rabara et al. (2014) also observed a significant amount of correlation of culm number with the panicle number; while, Moukoumbi et al. (2011) reported that the tall rice landraces had long and wide leaves. Filled or productive tiller, on the other hand, was correlated (moderately) with the leaf width, but strongly correlated with the total tiller. Thus, leaf width may have contributed to the productivity of the tiller.

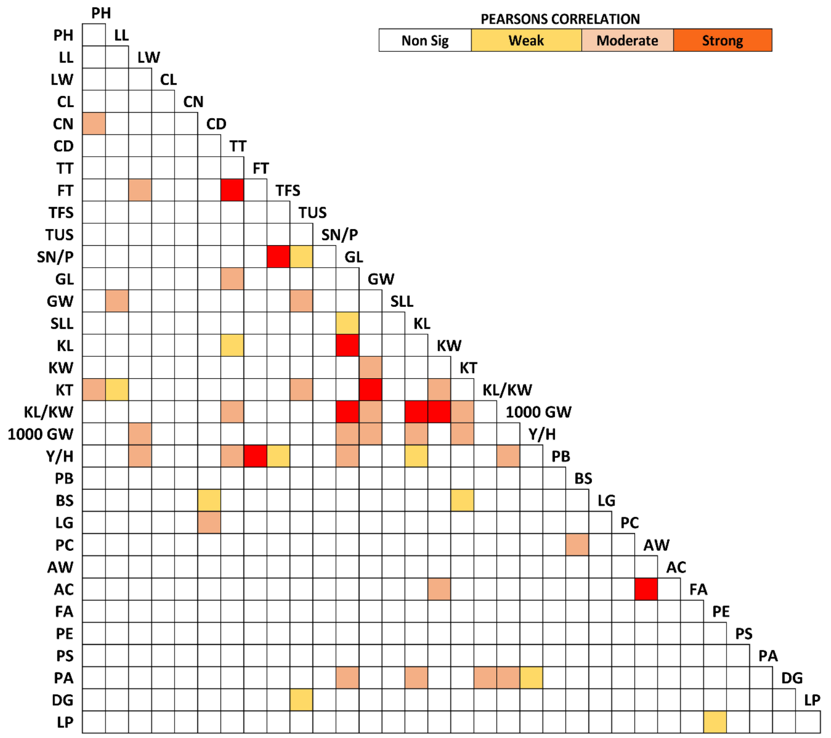

Figure 1. Heat Map of Correlation: The heat map of Pearsons correlation at alpha=0.05, displaying strong (1.8 %), weak (2.23%) and moderate (5.69%) correlation for 32 agro-morphological traits of indigenous rice in Eastern Himalaya

Note: PH= Plant height; LL= Leaf length; LW= Leaf width; CL= Culm length; CN=Culm number; CD= Culm diameter; TT= Total tiller; FT= Filled Tiller; TFS= Total filled spikelet; TUS= Total unfilled spikelet; SN/P= Spikelet number per panicle; GL= Grain length; GW= Grain width; SLL= Sterile lemma length; KL= Kernel length; KW= Kernel width; KT= Kernel thickness; KL/KW= ratio of kernel length and kernel width; 1000 GW= 1000 Grain weight; Y/H= Yield per hectare; PB=Leaf pubescence BS= Basal leaf sheath color; LG= Leaf intensity of green color; PC= Panicle curvature; AW= Awning; AC=Awn color; FA= Flag leaf angle; PE=Panicle exertion; PS= Panicle secondary branching; PA= Panicle attitude of branching; DG= Decorticated grain color; LP= Grain lemma and palea

Spikelet number per panicle was correlated strongly with total filled spikelet, but weakly with the total unfilled spikelet. The ratio of kernel length and width was moderately correlated with total tiller, grain width and kernel thickness; while, strongly correlated with grain length, kernel length and kernel width. Moderate correlation was also observed for grain width with leaf length and total unfilled spikelet. Moreover, the kernel thickness was moderately correlated with plant height and weakly correlated with the leaf length, which shows the role of plant height and leaf length in thickening of kernels.

Weak correlation was observed between sterile lemma length and grain length. Kernel length was weakly correlated with total tiller, but strongly with the grain length. Kernel width, on the other hand, was strongly correlated with grain weight. One thousand grain weight was moderately correlated with leaf width and all the grains related traits (grain length and width; kernel length and thickness). The correlation analyses of grain yield with other agronomic traits revealed the importance of productive tillers, leaf width, total tiller, grain length and decorticated grain thickness in the heightening of grain yield.

Qualitative characters such as basal leaf-sheath color were observed to be correlated (weak) with culm diameter and kernel thickness. The correlation was also detected between leaf intensity of green color and culm diameter. Panicle curvature was moderately correlated with the basal leaf sheath color. Awn color was also correlated with kernel width and awning property. The panicle attitude of branching was moderately correlated with the grain related traits (grain length, kernel length, kernel length and width ratio and 1000 grain weight); while, weakly correlated with grain yield. Decorticated grain color was weakly correlated with the total unfilled spikelet. Leaf pubescence was moderately correlated with panicle exertion.

The traits with strong positive correlations are the heritable and genetically controlled traits which could be transmitted into desired genotypes (Kisua et al., 2015). The traits that had moderate to high correlations, however, could be further used as a base for the utilization for the breeding purposes as well as for planning future germplasm collection targeting the specific traits.

Multivariate Cluster Analysis and Principal Component Analysis

The variation among the rice genotypes was revealed by cluster analysis using the UPGMA and Euclidean distance. A wide range of genetic distance ranged from 10 to 757, indicates the existence of high genetic diversity. Three different clusters based on hierarchical clustering was obtained (Figure 2), irrespective of their inhabiting geographical locations. In the truncated tree, cluster-I had 15, cluster-II had 20 and cluster-III had 6 accessions. Duplicates were not reported among the accessions in the cluster analysis. The minimum distance score of 10 was recorded between the population of ACC47 and ACC48, indicating the high genetic similarity. While, the maximum distance of 757 was observed between ACC46 and ACC49.

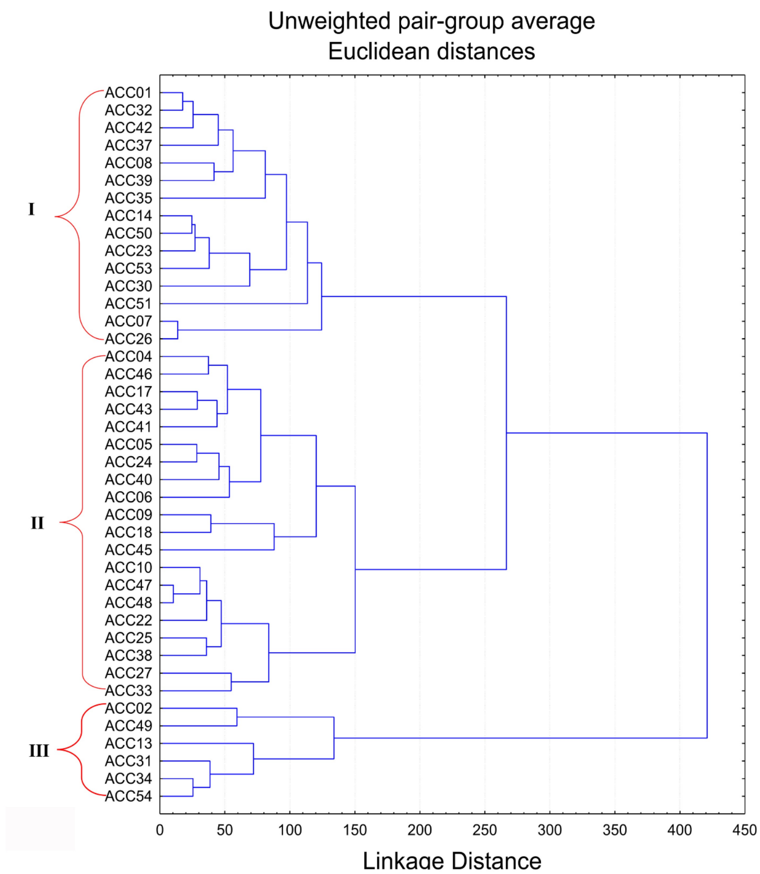

Figure 2. Multivariate Analysis of 32 agronomic traits of indigenous rice of Eastern Himalaya: Dendrogram showing 3 clusters, generated using Euclidean distance and UPGMA clustering for 41 indigenous rice accessions

Based on the morphological data, three distinct clusters were observed (Table 4). The members of Cluster-I have average plant height (ranges from 149.00 to 173.50 cm) and leaf width (ranges from 2.12 to 2.46 cm). The cluster was observed with a maximum total number of tillers (ranges from 7.80 to 13.60) and culm diameter. The grain yield is very high and thousand grain weights were scored maximum in this group (16.84 to 28.69 g). The cluster also has a maximum number of productive tillers (except ACC30). They also share qualitative characters such as, green basal leaf-sheath color, light green colored leaves, semi straight panicle curvature of main axis, well exerted panicles, strong secondary branching, white decorticated grain color and straw colored grain lemma and palea. Accessions ACC08, ACC04 and ACC30 have brown, while ACC42 have purple furrow on straw colored lemma and palea.

Table 4
List of rice accessions arranged in 3 groups according to the cluster analysis

Cluster Groups	Rice Accessions
Group 1	ACC01, ACC32, ACC42, ACC37, ACC08, ACC39, ACC35, ACC14, ACC50, ACC23, ACC53, ACC30, ACC51, ACC07 and ACC26
Group 2	ACC04, ACC46, ACC17, ACC43, ACC41, ACC05, ACC24, ACC40, ACC06, ACC09, ACC18, ACC45, ACC10, ACC47, ACC48 ACC223, ACC25, ACC38, ACC27 and ACC33.
Group 3	ACC02, ACC49, ACC13, ACC31, ACC34 and ACC54.

In case of cluster-II, the members were observed with a maximum culm number. The group displayed least number of total tillers as well as productive tillers, less thousand grain weight and average grain yield. Maximum individuals were observed with weak leaf pubescence, green colored basal leaf sheath, light green leaves, straight panicle curvature, no awns (ACC09 and ACC22), well exerted panicles, strong panicle secondary branching, semi erect branching of panicles, white decorticated grain color and lemma and palea of varied colors. Interestingly, most of the members scored highest in all the phenotypic traits.

Cluster-III accessions were recorded with the maximum score for all the grain related traits. The accessions are tall, and have a maximum total number of tillers and productive tillers. The score for the spikelet number per panicle and grain length was very low. They also shared qualitative characters such as, medium and strong leaf pubescence, green leaf sheath color (except ACC04 with purple), light green leaves (except ACC54 with dark green), semi-straight curvature of panicles, awnless, well exerted panicles, strong panicle secondary branching, semi-straight branching of panicles, white decorticated panicles and straw colored lemma and palea (except ACC31 having red color).

To supplement the cluster analysis, PCA was engaged to reduce the complexity of the dataset. Out of thirty independent principal components (PCs), top five PCs cumulatively account for 51.74% of the variance. According to Clifford and Stephenson (1975), the first three PCs play imminent role in reflection of varying patterns, thus, only first three PCs was used for the analysis. Individual analysis of the factor loadings of the characters in the retained PCs showed that grain related traits have highest positive factor loadings in PC1. These traits were grain length, kernel length and yield per hectare score with factor loadings of 0.8052, 0.7575 and 0.7618 respectively. These three morphological characters could have contributed to the maximum variability in PC1 which explained 15.30% of the total variation in the dataset. Similarly, in PC2 the grain related traits were observed with maximum positive factor loading. Thus, grain width, kernel width and kernel thickness were the major morphological characters that have contributed to the variation in PC2, which explained 16.30% of the variance. In case of PC3, morphological traits such as total filled spikelet, spikelet number per panicle and awning showed a high loading of 0.7998, 0.8049 and 0.4647 respectively, which accounts for 8.90% of the total variation.

The first two principal components (PC1 and PC2) cumulatively explained 27.61% of the total variance (Figure 3). In this combination, accessions ACC49, ACC35, ACC13, ACC34, ACC31, ACC54, ACC26, and ACC50 were observed with extremely high positive scores reflecting the highest contribution from 1000 grain weight, kernel thickness, grain yield, leaf width, filled tillers, leaf pubescence, awning, leaf intensity of green color, panicle curvature and plant height. On the other hand, accessions ACC24, ACC40, ACC42, ACC10, ACC46, ACC05, ACC09 and ACC04 showed low scores contributed from basal leaf-sheath color, total unfilled spikelet, leaf length, panicle secondary branching and decorticated grain color. Additionally, the results of this study also corroborate with those of Moukoumbi et al., (2011) in several aspects. Some exceptions were, however, also pointed out in terms of variations in cluster formation and grouping behaviors, which may be the result of the variations in environmental and soil edaphic factors.

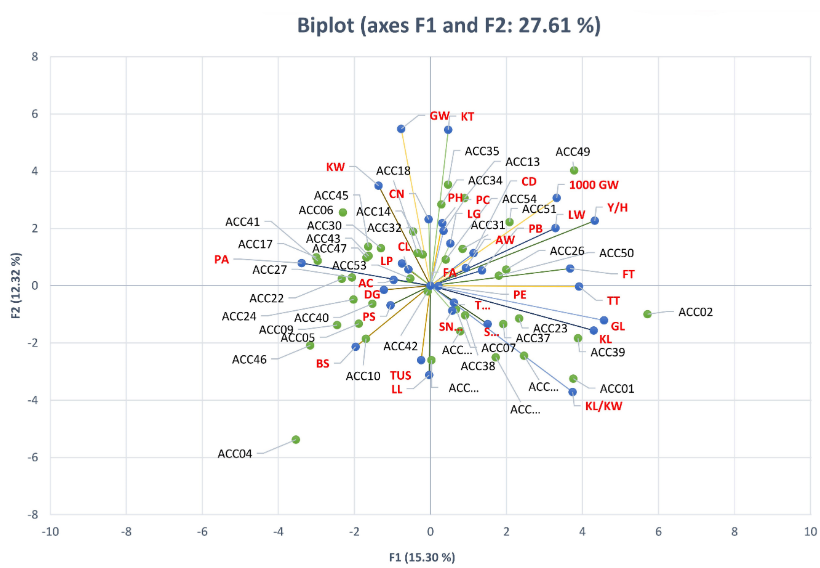

Figure 3. Multivariate Analysis of 32 agronomic traits of indigenous rice of Eastern Himalaya: Score biplot of F1 (PC1) and F2 (PC 2) based on 32 agro-morphological traits explaining 27.61% of total variance. Agro-morphological traits represented by blue colored dots, whereas rice accessions represented by green

CONCLUSIONS

The local inhabitants of this region are still maintaining their indigenous rice with its wide range of phenotypic traits in their jhum fields for many decades; and have optimized their entire practices corresponding to their diverse cultural and local ecological needs. The univariate as well as multivariate analysis of the agro-morphological traits had unveiled the existence of the ample polymorphism among the rice accessions. The results of the present experiment have noticeably specified the significance of the measured agro-morphological traits to identify naturally existing divergent clusters. It will be more suitable to make the selection of the traits based on plant height, leaf area, culm length, culm diameter, culm number, number of spikelet per panicle, productive tillers, grain length/breadth ratio, apparent grain yield and 1000 grain weight. The promising landraces including ACC01, ACC02, ACC04, ACC08, ACC23, ACC26, ACC27, ACC34, ACC38, ACC41, ACC49 and ACC51 could be used as a reservoir of valuable gene pool of indigenous rice. Multivariate analysis, including clustering pattern and PCA could also suggest the breeders about the appropriateness of different landraces of rice future endeavors. The above results also suggested that, the agro-morphological traits could be used efficiently to characterize the rice cultivars prior to documentation and subsequently on farms conservation of indigenous rice farms as well as in the seed banks.

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