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RESEARCH ARTICLE

# Morphometric, Physico-chemical and Micronutrient Characterization of Rice (*Oryza sativa* L.) Landraces of Sikkim Himalayas

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Rice landraces diversity of Sikkim consisting of 51 accessions were studied for morphological, physico-chemical and micronutrient diversity. Analysis of characterization data of 50 DUS characters and 16 physico-chemical traits showed considerable variation among the germplasm. While the landraces Redzomu and Taichung were earliest to flower, Doodhkalam, Taichung, Takmaru (LL), Baelbuty and Anandhi have short stem length and 17 other landraces are strongly aromatic. With regards to important quantitative traits maximum test weight was recorded in Anandhi (33.0 g), head rice recovery in Dudheyjuari and Tulasi (70.6%), kernel length in Kalsati (6.70 mm), grain iron (Fe) in Ramsaree (14.6 ppm) and maximum grain zinc (Zn) content in Chinidhan (30.2 ppm). The Pearson Correlation Coefficient for variables revealed associations among morphological and grain quality parameters. Multivariate Analysis indicated seven principal components (PCs) accounting for 80% of the variability in the rice germplasm and the UPGMA Cluster Analysis grouped the germplasm in to five distinct clusters.

**Key Words: DUS characters, Multivariate analysis, Northeastern India, Rice, Sikkim**

## Introduction

Northeastern region (NE) of India is a biodiversity hotspot rich in crop diversity (Myers *et al*., 2000). Globally, the region is considered as one of the hot pockets for rice genetic resources and a potential region with extremely diverse conditions for rice cultivation. Traditional cultivars are a storehouse for a number of desirable alleles which are the source material for tailoring genotypes for improved agronomic performance, resilience to stresses and enhancement of quality traits. For large scale adoption of new improved varieties, the best strategy is to breed for improvement of limiting traits without compromising the farmers' preferred traits. For that knowledge regarding the extent of genetic variation and relationships between genotypes is warranted. In this regard, morphological characterization helps in assessment of existing genetic diversity based on which new varieties were developed from germplasm (Sanni *et al.*, 2012; Chakravorty *et al.*, 2013). Rice grain quality is a major factor for varietal adoption by farmers which varies from region to region and is not universal. Although, this crop is a major source of nutrients to poor and vulnerable society, yet it doesn't contain sufficient levels of iron and zinc to meet the dietary requirements.

Sikkim is one of the Northeastern states nestled in the western part of East Himalayas and has been recently declared as the first organic state of India. Rice is the principal food crop of the region cultivated over varied altitudinal ranges and approximately covered an area of 11.16 (000´ ha) with production and productivity of 20.60 (000´ t) and 1815.74 (kg/ha) respectively during 2013-14 (Anonymous). The state is located on the old caravan route connecting India and Tibet and the local rice cultivars were introduced long time back and have established in the region (Subba, 2011). Moreover, the region has been reported to be the centre of differentiation of *Indica* and *Japonica* rices (Kihara and Katayama, 1963). Rice landraces of the Himalayan region have been studied and reported by various workers (Agnihotri and Palni, 2007; Rana *et al*., 2009 and Roy *et al*., 2016) however, few reports are available for Sikkim (Kihara and Katayama, 1963 and Kapoor *et al*., 2014). Due to small area of cultivation of landraces in remote and

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far-flung inhabitations, collection of all the local rice germplasm is rather difficult. Rice cultivars being grown in the state are adapted to sub-optimal conditions like low temperature, water stress and low manure/fertilizer inputs and knowledge with respect to their superior traits and genetic potential of these landraces remain unexplored. Grouping of cultivars on the basis of their respective traits unravels their strengths and weaknesses and improvement of these local cultivars for limiting traits through different breeding methodologies can be used effectively after proper characterization. As there are no studies carried out on morphological characterization, quality analysis and micronutrient content of rice landraces of Sikkim, hence, the present study has been undertaken to elucidate morphological variablity and grain quality parameters including micronutrient analysis for proper documentation and utilization of these genetic resources in rice improvement.

## Material and Methods

### *Experimental Material*

A total of two explorations were conducted during 2013 to collect germplasm samples of local rice landraces from different rice growing areas in all the four districts i.e East, West, North and South Sikkim from where a total of 51 rice accessions were assembled along with passport data containing place of collection, latitude, longitude, altitude, source of collection and special characters of the cultivar (Table 1). Seedlings of each of the 51 entries were planted on a row length of 3m at spacing of 20 × 20 cm in Augmented Randomized Complete Block Design with four checks namely PD-10, RCPL 123, RCPL 469 and RCPL 473 and raised under organic package of practices under irrigated environment from which five plants/entry were selected for data recording on quantitative and DUS descriptors. The experiment was conducted during *kharif* season of 2013 and 2014 at the experimental farm of ICAR-National Organic Farming Research Institute (NOFRI), Gangtok situated at 27º19'0''N and 88º36′0′′E at an elevation of 1320 msl.

### *Data Recording*

Data on quantitative traits for plant height (PH), days to heading (FL), number of tillers/plant (NOT), panicle length (PL), days to maturity (MAT), 1000 grain weight (SW) and yield/plant (YP) and on descriptors and states consisting of 51 DUS (Distinctiveness, Uniformity and Stability) characters of rice (PPV&FRA, Govt. of India) were recorded on randomly selected five plants. Also, recorded were grain quality parameters for 16 traits i.e hulling percentage (HL), milling percentage (ML), HRR (head rice recovery,) KL (Kernel length), KB (Kernel breadth), L/B (length breadth ratio), grain type, grain chalkiness, VER (volume expansion ratio), WU (water uptake), KLAC (kernel length after cooking), ER (elongation ratio), ASV (alkali spreading value), AC (amylose content), GC (gel consistency) and aroma as per standard procedures (IRRI, 1976). While the ASV was estimated following the method of Little *et al*., 1958 the GC test by the procedure using Cagampang *et al*., 1973 and the micronutrient analysis (Fe and Zn) by energy dispersive X–ray fluorescence spectrometry (XRF) as per the procedure of Rao *et al*., 2014.

### *Statistical Analysis*

Analysis of Variance for augmented randomized complete block design was computed (Federer, 1976), Pearson product-moment correlation for measuring relationships among 19 traits, principal component analysis for data reduction and for linear transformation of original variables in to new uncorrelated variables following standard procedures (Wiley, 1981) and cluster analysis for grouping rice germplasm using agglomerative UPGMA hierarchical method (Sneath and Sokal, 1973; Panchen, 1992). The software SAS 9.3 was used for statistical analysis of the data recorded (SAS, 2011).

## Results and Discussion

Local rice landraces of Sikkim exhibited considerable variation with respect to plant characters, grain quality parameters and iron and zinc content. Analysis of Variance showed significant differences among the cultivars for plant height, panicle length, number of tillers/plant, days to 50% heading, days to maturity, 1000 grain weight and yield/plant. Plant height recorded tallest in *Tulasi* (214.20 cm) while shortest in *Doodhkalam* (66.0 cm). *Bhangeri* was the highest tiller bearing cultivar (19.0) followed by *Attey* (18.0). *Krishnabhog* and *Dhutraj* bear long panicles of 29.20 and 28.0 cm respectively while *Sanoattey*, *Taichung* and *Ramzeera* were short panicle bearing cultivars. Heading started at 88$^{th}$ day in *Red zomu* while it took 131 days for *Kalonunia*. Earliest maturing cultivars were *Redzomu* (121 days), *Taichung* (123 days) and *Kalodhan* (125 days) while *Kalonunia*, *Krishnabhog*, *Brihmphool*, *Khimti* and *Sanokhamti* were last to mature (> 160 days). Highest grain yield per plant recorded in *Japani* (42.54 g/plant), however, *Taichung*, *Kaleybungey*, *Dudheyjauri*, *Pahelodalle* and *Attey* were relatively higher yielding (>30g/plant).

**Table 1. Passport data with source and location of rice landraces collected from Sikkim Himalayas**

| S.No | Landrace | Place of collection | Latitude | Longitude | Altitude |
|---|---|---|---|---|---|
| 1 | Red Zomu | Passingdang, North Sikkim | N 27$^{o}$33.186’ | E 088$^{o}$28.586’ | 4882 ft |
| 2 | Nepal Dhan | Lower Lingthem, North Sikkim | N 27$^{o}$31.660’ | E 088$^{o}$30.787’ | 3519 ft |
| 3 | Zomu | Pentong, North Sikkim | N 27$^{o}$29.258’ | E 088$^{o}$28.913’ | 5770 ft |
| 4 | Takmaru | Pentong, North Sikkim | N 27$^{o}$29.258’ | E 088$^{o}$28.913’ | 5770 ft |
| 5 | Takmaru LL | Sahgyong, North Sikkim | N 27$^{o}$24.529’ | E 088$^{o}$33.316’ | 5341 ft |
| 6 | Zokub | Lower Lingthem, North Sikkim | N 27$^{o}$31.603’ | E 088$^{o}$30.383’ | 4139 ft |
| 7 | Chini Dhan | Upper Lingthem, North Sikkim | N 27$^{o}$31.381’ | E 088$^{o}$29.970’ | 4944 ft |
| 8 | Taichung | Ramthang, North Sikkim | N 27$^{o}$24.648’ | E 088$^{o}$33.407’ | 5469 ft |
| 9 | Dharmali | Ramthang, North Sikkim | N 27$^{o}$24.529’ | E 088$^{o}$33.316’ | 5341 ft |
| 10 | Kalo Dhan | Sahgyong, North Sikkim | N 27$^{o}$29.258’ | E 088$^{o}$28.913’ | 5770ft |
| 11 | Pahelo Dalle | Yangthang, West Sikkim | N 27$^{o}$17.366’ | E 088$^{o}$14.015’ | 4924 ft |
| 12 | Tauli | Burmoik (Sumbok), West Sikkim | N 27$^{o}$15.784’ | E 088$^{o}$15.087’ | 3675 ft |
| 13 | Brihmphool | Toyang, West Sikkim | N 27$^{o}$16.637’ | E 088$^{o}$14.088’ | 3438 ft |
| 14 | Dudhey Juari | Hee Yangthang, West Sikkim | N 27$^{o}$16.837’ | E 088$^{o}$14.529’ | 4769 ft |
| 15 | Sijali | Rato Matey, Thamsing, West Sikkim | N 27$^{o}$14.923’ | E 088$^{o}$14.460’ | 4283 ft |
| 16 | Bhangeri | Sumbok, West Sikkim | N 27$^{o}$15.559’ | E 088$^{o}$14.435’ | 3741 ft |
| 17 | Ram Saree | Sasbote, West Sikkim | N 27$^{o}$08.889’ | E 088$^{o}$ 12.650’ | 1559 ft |
| 18 | Dhutraj | 5$^{th}$ Mile, Budang, West Sikkim | N 27$^{o}$07.988’ | E 088$^{o}$13.109’ | 1814 ft |
| 19 | Ram Bhog | East Sikkim | – | – | – |
| 20 | Japani | Malbasey, West Sikkim | N 27$^{o}$08.863’ | E 088$^{o}$12.657’ | 2387 ft |
| 21 | Kalsati | Toyang(GPU, Yangthang), West Sikkim | N 27$^{o}$16.838’ | E 088$^{o}$14.529’ | 3195 ft |
| 22 | Lal Bacchi | 5$^{th}$ Mile (Budang), West Sikkim | N 27$^{o}$07.988’ | E 088$^{o}$13.109’ | 1814 ft |
| 23 | Musuli | South Sikkim | – | – | – |
| 24 | Katti | 8$^{th}$ Mile (Budang), West Sikkim | N 27$^{o}$08.889’ | E 088$^{o}$12.650’ | 2390 ft |
| 25 | Marsee | East Sikkim | – | – | – |
| 26 | Kataka | Upper Tharpu, West Sikkim | N 27$^{o}$08.848’ | E 088$^{o}$11.433’ | 3153 ft |
| 27 | Champey | Toyang(GPU, Yangthang), West Sikkim | N 27$^{o}$16.838’ | E 088$^{o}$14.529’ | 3195 ft |
| 28 | Doodh Kalam | Gerethang, West Sikkim | N 27$^{o}$18.185’ | E 088$^{o}$13.802’ | 4450 ft |
| 39 | Kaley Bungay | 13$^{th}$ Mile, Sumbog, West Sikkim | N 27$^{o}$15.361’ | E 088$^{o}$14.557’ | 4555 ft |
| 30 | Khimti | Rinchinpong (Burfok), West Sikkim | N 27$^{o}$15.873’ | E 088$^{o}$15.732’ | 2836 ft |
| 31 | Timburay | Rungdhu, West Sikkim | N 27$^{o}$15.781’ | E 088$^{o}$15.086’ | 2868 ft |
| 32 | Phouryal | Lower Martam, West Sikkim | N 27$^{o}$15.909’ | E 088$^{o}$13.922’ | 3350 ft |
| 33 | Ram Zeera | West Sikkim | – | – | – |
| 34 | Sano Khamti | North Sikkim | – | – | – |
| 35 | Bael Butty | Barthang, South Sikkim | N 27$^{o}$15.348’ | E 088$^{o}$15.013’ | 3014 ft |
| 36 | Tulasi | Rungdhu, West Sikkim | N 27$^{o}$15.827’ | E 088$^{o}$15.149’ | 2692 ft |
| 37 | Chari Masini | Rabitar, South Sikkim | N 27$^{o}$07.963’ | E 088$^{o}$16.775’ | 3910 ft |
| 38 | Anandhi | South Sikkim | – | – | – |
| 39 | Chari Nangrey | South Sikkim | – | – | – |
| 40 | Yeidehi | West Sikkim | – | – | – |
| 41 | Khamti | Lower Tharpu, West Sikkim | N 27$^{o}$08.562’ | E 088$^{o}$11.423’ | 2889 ft |
| 42 | Tabrey | Ramthang, North Sikkim | N 27$^{o}$24.529’ | E 088$^{o}$33.316’ | 5341 ft |
| 43 | Jhapaka | 8$^{th}$ Mile Budang, West Sikkim | N 27$^{o}$08.889’ | E 088$^{o}$12.650’ | 2390 ft |
| 44 | Attey | Namprik, North Sikkim | N 27$^{o}$33.186’ | E 088$^{o}$28.586’ | 4882 ft |
| 45 | Zornali | East Sikkim | – | – | – |
| 46 | Chirakey | East Sikkim | – | – | – |
| 47 | Thulo Attey | Kaluk Rasi, West Sikkim | N 27$^{o}$13.344’ | E 088$^{o}$14.333’ | 4527 ft |
| 48 | Sano Attey | 13$^{th}$ Mile, Sumbog, West Sikkim | N 27$^{o}$15.361’ | E 088$^{o}$14.557’ | 4555 ft |
| 49 | Krishna Bhog | 5$^{th}$ Mile Budang, West Sikkim | N 27$^{o}$08.188’ | E 088$^{o}$13.076’ | 2151 ft |
| 50 | Phool Patta | East Sikkim | – | – | – |
| 51 | Kalo Nunia | 5$^{th}$ Mile Budang, West Sikkim | N 27$^{o}$08.188’ | E 088$^{o}$13.076’ | 2151 ft |

Cultivars like *Tulasi*, *Dhutraj*, *Krishnabhog*, *Rambhog*, *Kataka*, *Marsee*, *Tauli*and *Attey* are preferred by local farmers due to their tall stature which yield high biomass. Roy and Sharma (2014) studied 84 rice landraces and reported a cultivar with maximum 1000 seed weight with 32.04 g and also recorded the earliest maturing cultivar with 97 days.

### Characterization for DUS descriptors and states

Frequencies for DUS descriptors and states were worked out in rice germplasm and the same have been shown in Table 2. Various basal leaf sheath color appeared such as green, uniform purple, light purple and with purple lines. Leaf anthocyanin coloration was present in *Kalonunia*, *Pahelo Dalle*, *Yeidehi* and *Ramzeera*. Anthocyanin coloration was present on tips in most of the genotypes except in *Rambhog* and *Kalonunia* in which coloration was on margins. Leaf auricles were absent in *Krishnabhog*, *Rambhog, Phoolpatta, Ramzeera* and *Musuli.* Anthocyanin colour of collar appeared in *Timburey* and *Yeidehi*. Flower stigma was yellow in *Rambhog*, purple in *Redzomu*, *Chinidhan*, *Timburey* and *Yeidehi* while white coloured in rest of the cultivars. Panicle number per plant was few (<11) in majority of germplasm. *Kalodhan, Tabrey*, *Chinidhan, Takmaru, Kalonunia* and *Brihmphool* bear awned panicles. 1000 grain weight recorded highest in *Anandhi* (33.0g) however *Zomu, Kalsati, Tabrey, Dudheyjuari, Redzomu*, *Dhutraj, Kataka, Japani, Chirakey* and *Taichung*bear heavy grains (26-30g/1000 grain weight). These can be used as donor parents in hybridization programmes or as recurring parents for improving one or two agronomically inferior traits as most of the landraces lacked characters for high yield. As paddy straw is a limitation in Sikkim, farmers prefer tall cultivars inspite of their low yields as agriculture is basically a subsistence activity and high yield is not a priority for the farmers and indeed breeding local cultivars for high yield without compromising plant height is a challenge for the breeders. Landrace *Attey* is most widely cultivated in the region having good quality grain with tall plant habit but the long maturity duration needs to be reduced. Likewise, varieties *Red zomu* and *Kalodhan* although early maturing are low yielding. *Kalonunia, Brihmphool* and *Krishnabhog* are popular as aromatic rice needs improvement in seed yield and reduction in days to maturity. *Kalsati* having long kernels, medium amylose content and tall habit is a quality rice but needs to be improved for medium maturity duration to best fit in the local cropping system.

Genotypes *Krishnabhog, Kalonunia, Brihmphool, Khimti* and *Charinangrey* which are aromatic and have medium slender grains are best choice for market purpose but need improvement for high grain yield and medium maturity duration. Many rice workers evaluated rice genetic resources using DUS characters and mention may be made of Chakravorty and Ghosh (2012) who used 46 traits following DUS tests to characterize 51 rice landraces. Subba Rao et al., (2013) used 43 traits to characterize 65 rice landraces and Tripathy *et al*., (2014) who used 23 characters to characterize 91 early duration landraces.

### Grain Quality Parameters

There are no universal quality parameters for rice as it varies from region to region. The variability for grain quality parameters in rice landrace germplasm of Sikkim Himalayas has been depicted in Table 4. Head rice recovery is one of the most important traits from milling point of view which is influenced by a number of factors but chalky grains are more prone to breakage during milling. Maximum head rice recovery was recorded in *Dudhey Juari* and *Tulasi* (70.6%) and the minimum in *Brihmphool* (38.3%). Short bold type grains predominate the rice collections. *Dhood Kalam* and *Kalsati* bear long slender grains while *Krishnabhog, Kalonunia, Brihmphool, Khimti, Charinangrey* and *Musuli* were of medium slender type. Grain chalkiness was absent in *Taichung, Ramsaree, Krishnabhog, Kalonunia*, *Dhood Kalam, Pahelo Dalle* and *Anandhi*. Amylose content strongly influence the cooking and eating characteristics of rice. Rice with high amylose content (25-30%) tends to cook firm and dry, whereas rice with intermediate amylose content (20-25%) is generally soft and sticky whereas with low amylose content (<20%) cooks soft and sticky. Amylose content ranged from 14.9 to 25.87%. Grains of thirty six cultivars contain medium amylose content while thirteen have low amylose content and one contain high amylose. Kernel length after cooking was highest for *Kalsati* followed by *Nepal Dhan* and *Yeidehi*. Strongly scented aroma observed in 17 entries while 10 were medium scented. Rice with gelatinization temperature at the lower end often cooks to a softer texture and retrogrades less than the rice with a gelatinization temperature at the upper end. Gel consistency measures the tendency of the cooked rice to harden on cooling. *Red zomu*, *Kalo Dhan*, *Taichung*, *Pahelo Dalle*, *Phouryal*, *Timburey, Thulo attey* and *Anandhi* had soft gel consistency

**Table 2. Frequencies for DUS descriptors and states recorded on rice landraces from Sikkim Himalayas**

| S. No. | Descriptor | Descriptor state (Frequency %) |
|---|---|---|
| 1. | Coleoptile colour | Colourless (100%) |
| 2. | Basal leaf sheath colour | Green (84%): purple lines (6%): uniform purple (2 %): light purple (8%) |
| 3. | Leaf intensity of green color | Medium (94%): light (6%) |
| 4. | Leaf anthocyanin coloration | Present (8%): absent (92%) |
| 5. | Leaf: distribution of anthocyanin coloration | On margins (4%): on tips (96%) |
| 6. | Leaf sheath anthocyanin coloration | Present (12%): absent (88%) |
| 7. | Leaf sheath : intensity of anthocyanin coloration | Medium (4%): weak (6%): very weak (90%) |
| 8. | Leaf pubescence of leaf blade | Weak (36%): absent (24%): medium (30%): strong (10%) |
| 9. | Leaf auricles | Absent (10%): present (90%) |
| 10. | Leaf anthocyanin coloration of auricles | Colorless (56%): light purple (44%) |
| 11. | Leaf collar | Present (100%) |
| 12. | Leaf anthocyanin coloration of collar | Present (4%): absent (96%) |
| 13. | Leaf ligule | Present (100%) |
| 14. | Shape of ligule | Split (100%) |
| 15. | Leaf: colour of ligule | Light purple (6%): white (94%) |
| 16. | Leaf length of blade | Medium (16%): long (84%) |
| 17. | Leaf width of blade | Narrow (26%): medium (74%) |
| 18. | Culm attitude | Semi-erect (30%): open (2 %): erect (68%) |
| 19. | Time of heading (50% of plants with panicles) | Early (8%): late (40%): medium (52%) |
| 20. | Flag leaf attitude (early observation) | Erect (98%): erect (2%) |
| 21. | Spikelet: density of pubescence of lemma | Strong (22%): very strong (2%): weak (10%): medium (66%) |
| 22. | Male sterility | Absent (100%) |
| 23. | Lemma: anthocyanin coloration of keel | Very strong (2%): strong (2%): weak (4%): absent (92%) |
| 24. | Lemma: anthocyanin coloration of area below apex | Very strong (2%): strong (10%): weak (4%): absent (84%) |
| 25. | Lemma: anthocyanin coloration of apex | Very strong (8%): strong (12%): weak (4%): absent (76%) |
| 26. | Spikelet color of stigma | Purple (8%): yellow (2%): white (90%) |
| 27. | Stem thickness | Thick (24%): thin (4%): medium (72%) |
| 28. | Stem length | Very short (6%): short (4%): medium (42%): long (32%): very long (16%) |
| 29. | Stem anthocyanin colouration of nodes | Present (4%): absent (96%) |
| 30. | Stem anthocyanin colouration on internodes | Absent (100%) |
| 31. | Panicle: length of main axis | Long (32%): medium (68%) |
| 32. | Flag leaf attitude of blade(late observation) | Erect (100%) |
| 33. | Panicle: curvature of main axis | Straight (12%): semi-straight (8%): semi-erect (4%): deflexed (76%) |
| 34. | Panicle number per plant | Medium (2%): few (98%) |
| 35. | Spikelet: colour of tip of lemma | Black (12%): purple (10%): yellow (6%): brown (72%) |
| 36. | Lemma and palea colour | Straw (36%): brown furrows on straw (16%): brown tawny (32%): purple black (8%): brown spots on straw (8%) |
| 37. | Panicle awns | Absent (88%): present (12%) |
| 38. | Panicle: presence of secondary branching | Present (100%) |
| 39. | Panicle secondary branching | Strong (64%): weak (36%) |
| 40. | Panicle attitude of branches | Erect to semierect (22%): semierect (70%): erect (2%): semierect to spreading (6%) |
| 41. | Panicle exertion | Mostly exerted (6%): well exerted (94%) |
| 42. | Time maturity | Medium (8%): late (54%): very late (38%) |
| 43. | Leaf senescence | Late (50%): medium (50%) |
| 44. | Sterile lemma colour | Red (10%): purple (12%): straw (78%) |
| 45. | Grain: weight of 1000 fully developed grains | Low (42%): high (6%): medium (52%) |
| 46. | Grain length | Very short (84%): short (16%) |
| 47. | Grain width | Narrow (6%): medium (56%): long (38%) |
| 48. | Grain shape | Short bold (72%): medium slender (12%): long bold (12%): long slender (4%) |
| 49. | Content of amylose | Low (26%): medium (74%) |
| 50. | Gelatinization temperature | Low (94%): medium (6%) |
| 51. | Aroma | Strongly scented (34%): medium scented (22%): non scented (44%) |

**Table 3. Promising rice landraces identified against important traits**

| | Character | Cultivars |
|---|---|---|
| Time of heading | Early (71 -90 days) | Red zomu, Tabrey, Zomu, Taichung |
| Stem length | Very short (< 91 cm) | Doodh Kalam, Taichung, Takmaru (lowland) |
| | Short (91-110 cm) | Bael Buty, Anandhi |
| 1000 grain weight | Very high (> 30g) | Anandhi |
| | High (26-30 g) | Zomu, Kalsati, Tabrey, Dudhey Juari, Red zomu, Dhutraj, Japani, kataka, Chirakey, Taichung |
| Stem thickness | Thick (> 0.55 cm) | Krishnabhog, Kataka, Rambhog, Japani, Lal bacchi, Sano attey, Kalsati, Khimti, Ramzeera, Zornalli, Sano khamti |
| Panicle length | Long (26-30 cm) | Krishnabhog, Tulasi, Dhutraj, Rambhog, Zornalli, Sijali, Tauli, Takmaru lowland, Dudhey juari, Attey, Chirakey, Bhangeri, Japani, Phool patta, Ramsaree, Kataka, Chini dhan, Kaley bungey, Champey, Brihmphool |
| Panicle: curvature of main axis | Straight | Champey, Khimti, Zomu, Jhapaka, Khamti, Katti, |
| Kernel length | Long (> 6.60 mm) | Kalsati |
| | Medium (5.50 mm–6.60 mm) | Doodh kalam, Dhutraj, Japani, Charimasini, Phouryal, Champey, Zornalli, Nepal dhan, Khimti, Anandhi, Kataka, Zomu, Lal bacchi |
| Maturity | Medium (121-140 days) | Red zomu, Taichung, Kalodhan and Tabrey |
| Aroma | Strongly scented | Kalo dhan, Tabrey, Ramsaree, Krishnabhog, Rambhog, Kalonunia, Lal bacchi, Chari masini, Pahelo dalle, Tauli, Brihmphool, Kalsati, Khimti, Anandhi, Phool patta, Chari nangrey, Ramzeera |

(61-100), this is a preferred character as the cooked rice has high degree of tenderness. The time required for cooking milled rice is determined by gelatinization temperature (GT). GT of milled rice is determined by evaluating the alkali spreading value. It correlates positively with the time required to cook rice. High alkali spreading value recorded for most of the cultivars which denotes low gelatinization temperature (55$^{o}$ to 69 ºC). Consumers prefer length wise elongation of rice kernels and is influenced by factors like type of genotype, water uptake, amylose content, gelatinization temperature, aging and water uptake. KLAC varies from 7.7 mm in *Kaleybungey* to 15.5 mm in *Kalsati*. However elongation ratio recorded highest for *Takmaru* (lowland type) 5.2 mm. Values of volume expansion ratio were high in *Sijali* and *Dhutraj* (5.6 each) while low in *Tauli, Lal Bacchi* and *Attey* (4.0). It is a positive character for lower income group farmers for whom quantity is important, however more the volume expansion ratio, less will be energy content per unit volume. Rice with low amylose content which cooks sticky are preferred in Manipur, Nagaland and Mizoram and some parts of Arunachal Pradesh while short slender to medium slender with intermediate amylose content are preferred in Assam, Tripura and Sikkim. Short and bold grains with intermediate amylose content which become fluffy on cooking are mostly preferred in Sikkim. Subudhi *et al.* (2012) reported that HRR (%) in rice germplasm varied from 43.5% to 68.0% while kernel length after cooking from 7.9 to 12.5 mm in 41 rice varieties. Bajpai *et al.* (2012) reported elongation ratio of 1.60-2.33 mm in Kalanamak rice collections. Verma *et al.* (2015) found variation from 2.0-24.5% in amylose content while grain length after cooking varied from 5.5-12.7 mm. Devi *et al.* (2008) studied 15 important indigenous rice genotypes from different rice ecosystems of Northeastern India of which majority of rice genotypes were bold and amylose content varied from 2.3-24.5% while Devi *et al.* (2012) studied rice quality parameters in 18 indigenous rice cultivars of Tripura of which majority of them have low amylose content (< 20%). Aromatic rices have been popular in the state due to their quality traits and premium price in local market. A considerable variation in aromatic rice signifies ample scope of their improvement for reaping more economic benefits. Due to the complex inheritance of rice grain quality traits (Srivastava *et al.*, 2012) initial improvement can be made through pureline breeding through local selection and purification (Singh *et al.*, 2000). However, pedigree selection, backcross and convergent breeding can be employed for isolating superior segregants. Genetic enhancement employing pedigree method along with molecular markers were also employed for improvement of plant stature, aroma and grain quality traits (Patnaik *et al.*, 2015).

### *Iron and Zinc content*

Iron and Zinc content ranged from 6.4 to 14.6 ppm and 13.4 to 30.2 ppm, respectively (Table 5). Highest

**Table 4. Variability for grain quality parameters in rice landraces from Sikkim Himalayas**

| S No. | Landrace | Hulling (%) | Milling (%) | HRR (%) | KL (mm) | KB (mm) | L/B (mm) | Grain type | Grain Chalk | VER | WU | KLAC | ER | ASV | AC | GC | Aroma |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Red Zomu | 78.2 | 61.2 | 39.2 | 5.11 | 2.89 | 1.76 | SB | VOC | 4.1 | 270 | 9.8 | 1.91 | 5.0 | 20.26 | 64 | NS |
| 2 | Kalo Dhan | 82.4 | 67.5 | 64.9 | 5.01 | 2.54 | 1.97 | SB | OC | 4.8 | 280 | 9.8 | 1.95 | 7.0 | 22.02 | 67 | SS |
| 3 | Zokub | 78.7 | 70.7 | 70.4 | 3.73 | 2.42 | 1.54 | SB | OC | 4.2 | 275 | 12.0 | 3.21 | 7.0 | 17.77 | 22 | NS |
| 4 | Tabrey | 80.4 | 68.4 | 60.8 | 4.82 | 2.69 | 1.79 | SB | VOC | 4.6 | 265 | 11.0 | 2.28 | 7.0 | 21.13 | 50 | SS |
| 5 | ChiniDhan | 78.0 | 67.5 | 61.7 | 5.43 | 2.29 | 2.37 | SB | OC | 5.4 | 260 | 11.1 | 2.04 | 7.0 | 22.99 | 45 | NS |
| 6 | Nepal Dhan | 78.0 | 67.9 | 62.8 | 6.01 | 2.07 | 2.90 | LB | VOC | 4.8 | 370 | 14.6 | 2.42 | 7.0 | 17.95 | 43 | MS |
| 7 | Zomu | 76.2 | 65.0 | 59.2 | 5.62 | 2.63 | 2.13 | SB | VOC | 4.2 | 265 | 10.7 | 1.90 | 4.0 | 22.88 | 58 | NS |
| 8 | Takmaru | 76.2 | 65.0 | 65.0 | 4.32 | 2.65 | 1.63 | SB | OC | 4.5 | 220 | 8.1 | 1.87 | 6.0 | 21.88 | 50 | NS |
| 9 | Takmaru (Lowland type) | 79.2 | 69.3 | 65.8 | 2.26 | 2.50 | 1.70 | SB | OC | 4.6 | 275 | 11.8 | 5.22 | 7.0 | 24.55 | 48 | NS |
| 10 | Taichung | 80.8 | 71.3 | 68.6 | 4.56 | 2.91 | 1.56 | SB | A | 4.6 | 310 | 8.6 | 1.88 | 7.0 | 17.21 | 68 | NS |
| 11 | Jhapaka | 78.4 | 63.7 | 56.7 | 5.11 | 2.36 | 2.16 | SB | OC | 5.0 | 240 | 10.3 | 2.01 | 7.0 | 23.20 | 56 | NS |
| 12 | Khamti | 77.6 | 66.5 | 60.1 | 5.19 | 2.39 | 2.17 | SB | OC | 4.8 | 320 | 11.8 | 2.00 | 7.0 | 21.23 | 47 | NS |
| 13 | Katti | 77.2 | 66.6 | 66.2 | 4.12 | 2.38 | 1.73 | SB | OC | 4.1 | 200 | 11.6 | 2.81 | 7.0 | 21.53 | 47 | MS |
| 14 | Ram Saree | 79.7 | 70.6 | 70.2 | 3.82 | 2.50 | 1.52 | SB | A | 4.6 | 200 | 8.7 | 2.27 | 7.0 | 20.53 | 22 | SS |
| 15 | Dhut Raj | 78.0 | 68.7 | 65.6 | 6.51 | 2.26 | 2.88 | LB | OC | 5.6 | 300 | 14.2 | 2.18 | 7.0 | 18.94 | 52 | MS |
| 16 | Krishnabhog | 78.7 | 67.0 | 64.5 | 5.41 | 2.08 | 2.60 | MS | A | 4.6 | 120 | 14.2 | 2.62 | 6.0 | 22.46 | 60 | SS |
| 17 | Marsee | 76.7 | 67.3 | 64.3 | 4.81 | 2.57 | 1.87 | SB | VOC | 4.8 | 195 | 10.8 | 2.24 | 6.0 | 18.97 | 55 | NS |
| 18 | Kataka | 79.6 | 68.9 | 66.6 | 5.69 | 2.34 | 2.37 | SB | VOC | 5.4 | 290 | 10.5 | 1.84 | 7.0 | 21.23 | 22 | NS |
| 19 | Rambhog | 79.2 | 70.9 | 70.4 | 4.39 | 2.45 | 1.79 | SB | OC | 4.2 | 300 | 10.6 | 2.41 | 7.0 | 17.68 | 22 | SS |
| 20 | Japani | 74.8 | 69.2 | 66.4 | 6.33 | 2.20 | 2.87 | LB | OC | 4.8 | 260 | 13.4 | 2.11 | 7.0 | 19.27 | 42 | MS |
| 21 | Kalonunia | 77.7 | 67.2 | 63.2 | 5.46 | 2.10 | 2.60 | MS | A | 5.0 | 200 | 12.5 | 2.28 | 6.0 | 21.61 | 43 | SS |
| 22 | Lal Bacchi | 78.9 | 67.2 | 61.2 | 5.51 | 2.23 | 2.47 | SB | VOC | 4.0 | 295 | 12.8 | 2.32 | 7.0 | 20.76 | 22 | SS |
| 23 | Chari Masini | 79.8 | 69.2 | 65.6 | 6.31 | 2.22 | 2.84 | LB | VOC | 4.4 | 260 | 13.8 | 2.18 | 7.0 | 20.97 | 51 | SS |
| 24 | Champey | 69.8 | 60.2 | 53.8 | 6.02 | 2.02 | 2.98 | LB | VOC | 4.1 | 305 | 13.8 | 2.29 | 7.0 | 16.48 | 45 | NS |
| 25 | Dhood Kalam | 80.0 | 69.0 | 62.4 | 6.57 | 2.10 | 3.12 | LS | OC | 4.8 | 290 | 13.9 | 2.11 | 6.0 | 21.26 | 35 | NS |
| 26 | Pahelo Dalle | 77.8 | 68.0 | 66.1 | 5.17 | 2.12 | 2.43 | SB | A | 4.5 | 215 | 14.1 | 2.72 | 4.0 | 14.90 | 77 | SS |
| 27 | Tauli | 81.3 | 69.7 | 63.5 | 4.87 | 2.60 | 1.87 | SB | VOC | 4.0 | 305 | 11.9 | 2.44 | 7.0 | 23.90 | 58 | SS |
| 28 | Brihmphool | 78.3 | 60.6 | 38.3 | 5.19 | 1.99 | 2.60 | MS | VOC | 4.8 | 300 | 11.1 | 2.13 | 7.0 | 23.40 | 43 | SS |
| 29 | Dudhey Juari | 81.6 | 71.0 | 70.6 | 4.99 | 2.68 | 1.86 | SB | VOC | 5.5 | 310 | 11.1 | 2.22 | 7.0 | 22.90 | 52 | NS |
| 30 | Kaley Bungey | 78.8 | 68.8 | 67.9 | 3.89 | 2.53 | 1.53 | SB | VOC | 4.6 | 280 | 7.7 | 1.97 | 6.0 | 20.97 | 46 | MS |
| 31 | Bael Butty | 80.1 | 69.0 | 59.6 | 5.14 | 2.34 | 2.19 | SB | OC | 4.3 | 230 | 11.5 | 2.23 | 7.0 | 21.47 | 58 | NS |
| 32 | Sano Attey | 80.0 | 69.4 | 68.9 | 3.85 | 2.33 | 1.65 | SB | VOC | 4.6 | 225 | 8.8 | 2.28 | 7.0 | 20.70 | 60 | NS |
| 33 | Kalsati | 76.2 | 67.8 | 64.8 | 6.70 | 2.17 | 3.08 | LS | VOC | 4.6 | 295 | 15.5 | 2.31 | 6.0 | 17.68 | 51 | SS |
| 34 | Phouryal | 79.7 | 71.3 | 68.7 | 6.19 | 2.26 | 2.73 | LB | VOC | 5.4 | 335 | 13.8 | 2.22 | 7.0 | 18.24 | 61 | MS |
| 35 | Timburey | 79.4 | 65.4 | 64.7 | 4.09 | 2.73 | 1.49 | SB | VOC | 4.6 | 335 | 8.6 | 2.10 | 7.0 | 23.11 | 63 | MS |
| 36 | Thulo Attey | 79.5 | 69.3 | 65.7 | 4.75 | 2.55 | 1.86 | SB | VOC | 4.1 | 315 | 10.6 | 2.23 | 6.0 | 22.70 | 61 | MS |
| 37 | Tulasi | 80.9 | 71.3 | 70.6 | 4.21 | 2.65 | 1.58 | SB | VOC | 4.2 | 300 | 9.6 | 2.28 | 7.0 | 22.79 | 50 | MS |
| 38 | Sijali | 78.8 | 72.9 | 65.7 | 4.99 | 2.73 | 1.82 | SB | VOC | 5.6 | 305 | 11.2 | 2.24 | 7.0 | 25.87 | 55 | NS |
| 39 | Khimti | 77.6 | 66.5 | 60.1 | 5.90 | 2.14 | 2.75 | MS | OC | 4.8 | 320 | 11.8 | 2.00 | 6.0 | 17.62 | 53 | SS |
| 40 | Bhangeri | 76.3 | 65.4 | 64.8 | 4.60 | 2.57 | 1.78 | SB | VOC | 4.3 | 310 | 10.6 | 2.30 | 6.0 | 20.73 | 44 | NS |
| 41 | Anandhi | 79.4 | 65.5 | 57.8 | 5.87 | 2.82 | 2.08 | SB | F/A | 4.1 | 260 | 12.6 | 2.14 | 7.0 | 18.06 | 77 | SS |
| 42 | Phool Patta | 77.3 | 67.3 | 64.6 | 4.67 | 2.51 | 1.86 | SB | VOC | 4.2 | 395 | 11.7 | 2.50 | 7.0 | 22.82 | 54 | SS |
| 43 | Chari Nangrey | 78.9 | 68.8 | 64.5 | 5.45 | 1.93 | 2.82 | MS | VOC | 4.6 | 340 | 13.8 | 2.53 | 7.0 | 22.29 | 49 | SS |
| 44 | Yeidhei | 79.0 | 69.7 | 66.8 | 5.39 | 2.44 | 2.20 | SB | OC | 4.6 | 285 | 14.3 | 2.65 | 7.0 | 23.46 | 53 | NS |
| 45 | Ramzeera | 78.0 | 70.8 | 70.3 | 3.91 | 2.42 | 1.61 | SB | VOC | 4.6 | 305 | 8.0 | 2.04 | 7.0 | 23.49 | 54 | SS |
| 46 | Musuli | 78.7 | 67.3 | 61.1 | 5.36 | 1.94 | 2.76 | MS | VOC | 5.5 | 320 | 12.5 | 2.33 | 7.0 | 22.61 | 56 | MS |
| 47 | Zornalli | 79.4 | 68.8 | 61.6 | 6.02 | 2.27 | 2.65 | LB | OC | 4.6 | 320 | 13.5 | 2.24 | 6.0 | 21.64 | 55 | NS |
| 48 | Chirakey | 79.8 | 69.4 | 68.8 | 4.48 | 2.90 | 1.54 | SB | VOC | 4.5 | 230 | 9.1 | 2.03 | 5.0 | 20.76 | 52 | NS |
| 49 | Sano Khamti | 77.0 | 66.5 | 60.1 | 5.10 | 2.36 | 2.16 | SB | OC | 4.5 | 310 | 10.7 | 2.00 | 7.0 | 23.05 | 57 | MS |
| 50 | Attey | 81.8 | 71.4 | 68.0 | 4.65 | 2.56 | 1.81 | SB | VOC | 4.0 | 275 | 9.5 | 2.04 | 7.0 | 24.64 | 58 | NS |
| 51 | Dharmali | 82.0 | 69.6 | 63.2 | 5.88 | 2.55 | 2.30 | SB | VOC | 4.6 | 300 | 11.6 | 1.97 | 7.0 | 23.14 | 50 | NS |

* SB: Short bold; LB: long bold; MS: medium slender; LB: long bold; LS: long slender; VOC: very occasional; OC: occasional; A: absent; NS: non-scented; SS: strongly scented; MS: medium scented

**Table 5. Variability for Iron and Zinc content (ppm) in rice landraces from Sikkim Himalayas**

| S.No | Landrace | Fe | Zn | S.No | Landrace | Fe | Zn |
|---|---|---|---|---|---|---|---|
| 1 | Red Zomu | 12.7 | 25.3 | 27 | Tauli | 10.5 | 21.9 |
| 2 | Kalo Dhan | 9.7 | 18.0 | 28 | Brihmphool | 9.5 | 21.7 |
| 3 | Zokub | 9.6 | 20.5 | 29 | DudheyJuari | 10.1 | 19.8 |
| 4 | Tabrey | 8.7 | 21.5 | 30 | KaleyBungey | 10.4 | 21.0 |
| 5 | ChiniDhan | 10.1 | 30.2 | 31 | BaelButty | 8.8 | 23.5 |
| 6 | Nepal Dhan | 9.6 | 20 | 32 | Sano Attey | 10.8 | 22.3 |
| 7 | Zomu | 11.1 | 25.6 | 33 | Kalsati | 6.4 | 18.9 |
| 8 | Takmaru | 11.4 | 23.9 | 34 | Phouryal | 9.5 | 19.9 |
| 9 | Takmaru (Lowland type) | 9.1 | 20.4 | 35 | Timburey | 10.6 | 21.3 |
| 10 | Taichung | 12.1 | 26.8 | 36 | Thulo Attey | 10.1 | 21.9 |
| 11 | Jhapaka | 10.3 | 26.7 | 37 | Tulasi | 11.3 | 23.1 |
| 12 | Khamti | 8.0 | 19.1 | 38 | Sijali | 10.8 | 25.1 |
| 13 | Katti | 12.5 | 25.5 | 39 | Khimti | 10.5 | 20.6 |
| 14 | Ram Saree | 14.6 | 21.3 | 40 | Bhangeri | 10.8 | 16.2 |
| 15 | Dhut Raj | 9.9 | 16.1 | 41 | Anandhi | 11.1 | 19.8 |
| 16 | Krishnabhog | 10.2 | 13.6 | 42 | Phool Patta | 12.5 | 16.4 |
| 17 | Marsee | 12.7 | 20.5 | 43 | Chari Nangrey | 13.3 | 15.3 |
| 18 | Kataka | 8.7 | 22.6 | 44 | Yeidhei | 9.2 | 22.5 |
| 19 | Rambhog | 8.0 | 14.7 | 45 | Ramzeera | 11.6 | 16.9 |
| 20 | Japani | 9.6 | 18.1 | 46 | Musuli | 12.5 | 18.4 |
| 21 | Kalonunia | 8.2 | 13.4 | 47 | Zornalli | 9.8 | 20.2 |
| 22 | Lal Bacchi | 8.4 | 18.8 | 48 | Chirakey | 12.2 | 26.9 |
| 23 | Chari Masini | 8.6 | 21.9 | 49 | Sano Khamti | 10.4 | 27.3 |
| 24 | Champey | 7.9 | 18.0 | 50 | Attey | 11.2 | 23.4 |
| 25 | Dhood Kalam | 8.2 | 16.8 | 51 | Dharmali | 12.3 | 20.8 |
| 26 | Pahelo Dalle | 9.4 | 15.4 | | | | |

iron concentration in grains recorded for *Ramsaree* (14.6 ppm) followed by *Chari Nangrey* (13.3 ppm) while highest zinc content in *Chini Dhan* (30.2 ppm) followed by *Sano Khamti* (27.3 ppm). Grain iron and zinc content of a genotype depends on various factors such as the nature of grain, soil properties, time of harvest, phloem sap loading and unloading rates and genotype × environment interaction. Anuradha *et al.*, (2012) analysed brown rice samples of 126 accessions and reported grain iron and zinc concentration ranging from 6.2 ppm -71.7 ppm and 2.6-67.3 ppm, respectively while iron content of 6.6-16.7 ug/g and zinc of 7.1 to 32.4 µg/g in 192 brown rice accessions (Nachimuthu *et al.*, 2014). Biofortification programmes like Harvest plus and All India Coordinated Rice Improvement Project (AICRIP) have fixed 24 ppm as target for zinc in well polished rice grain and varieties having ≥24 ppm zinc content are promoted without compromising yield as well as grain quality. Mostly consumers prefer polished rice and percentage losses of iron and zinc during polishing were observed to be as high as 60 to 70% and 20 to 40%, respectively. Considering the above, nine landraces appeared to be promising for zinc content in polished rice, however, their performance in multiple locations within this region needs to be verified through a separate study. Iron content is low in brown rice which might be due to the soil properties as farming in Sikkim is low input and hardly any soil amendment is done.

### *Correlation Coefficients and Association*

Pearson Correlation Coefficient revealed associations among 19 variables (Table 6). Plant height showed positive significant correlation with panicle length (r=0.504). Days to maturity correlated positively with days to heading (r=0.740) along with low degree of association with kernel length, VER and KLAC. Yield/plant, seed weight and kernel breadth were negatively correlated with days to maturity. Kernel length (r=0.531), kernel breadth (r=0.278), KLAC (r=0.361) and gel consistency were positively correlated with 1000 seed weight. Kernel length showed positive correlation with KLAC while negative association with kernel breadth, elongation ratio and amylose content. Kernel breadth and KLAC were strongly negatively associated (r=-0.644). Head rice recovery showed high significant positive correlation (r=0.80) with milling percentage while negative correlation with kernel length and L/B ratio. Amylose content did not showed high correlation with any of the traits, however moderately positively correlated with hulling percent (r=0.26) and negatively correlated with kernel length (r=-0.29), L/B (r=-0.27) and KLAC (r=-0.32). ASV showed moderate positive correlation (r=0.26) with water uptake and negative correlation with gel consistency. Sinha and Mishra (2013) reported high correlation of 50% heading with maturity time and stem length and also of grain length and grain weight with kernel length and kernel weight respectively. Sharma *et al.* (2012) reported highest correlation between days to flowering and days to maturity, positive and significant correlation among grain weight, width and length.

### *PCA and Cluster Analysis*

Multivariate analytical techniques are important tools for classifying the germplasm and analyzing genetic relationships among breeding material (Mohammadi and Prasanna, 2003). These statistical algorithms are useful in delineating variability in germplasm and reducing the complex data of number of variables for meaningful inferences. Eigen values of the correlation matrix showed

**Table 6. Pearson Correlation Coefficient for 19 characters recorded on rice landraces from Sikkim Himalayas**

| | PH | FL | NOT | PL | MAT | YP | SW | KL | KB | VER | WU | KLAC | ER | ASV | AC | GC | HL | ML | HRR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | | 0.236 | 0.136 | 0.504* | 0.165 | -0.059 | -0.173 | -0.089 | 0.115 | 0.066 | -0.024 | -0.193 | -0.215 | 0.142 | 0.210 | -0.106 | 0.143 | 0.227 | 0.226 |
| FL | | | 0.071 | 0.045 | 0.740* | -0.075 | -0.393* | 0.021 | -0.378* | 0.122 | -0.107 | 0.071 | -0.018 | 0.371* | -0.003 | -0.306* | -0.264 | -0.070 | 0.122 |
| NOT | | | | 0.187 | 0.057 | 0.277 | -0.153 | -0.009 | -0.056 | 0.008 | 0.085 | -0.032 | -0.046 | 0.024 | 0.310* | 0.033 | -0.104 | 0.018 | 0.008 |
| PL | | | | | 0.062 | 0.107 | -0.015 | -0.056 | 0.039 | 0.097 | -0.013 | 0.056 | 0.162 | -0.011 | 0.209 | -0.291* | 0.045 | 0.138 | 0.102 |
| MAT | | | | | | -0.336* | -0.303* | 0.293* | -0.562* | 0.288* | -0.129 | 0.334* | -0.049 | 0.134 | 0.049 | -0.220 | -0.350* | -0.113 | -0.019 |
| YP | | | | | | | 0.090 | -0.118 | 0.141 | -0.050 | 0.262 | -0.033 | 0.146 | 0.072 | -0.117 | 0.130 | 0.084 | 0.293 | 0.290 |
| SW | | | | | | | | 0.531* | 0.278* | 0.096 | 0.183 | 0.361* | -0.148 | -0.164 | -0.177 | 0.329* | 0.018 | -0.110 | -0.196 |
| KL | | | | | | | | | -0.474* | 0.275 | 0.162 | 0.695* | -0.460* | -0.107 | -0.318* | 0.067 | -0.241 | -0.196 | -0.284* |
| KB | | | | | | | | | | -0.245 | -0.029 | -0.644* | -0.112 | -0.107 | 0.184 | 0.266 | 0.332* | 0.178 | 0.147 |
| VER | | | | | | | | | | | 0.094 | 0.133 | -0.134 | 0.194 | 0.113 | -0.026 | 0.065 | 0.172 | 0.104 |
| WU | | | | | | | | | | | | 0.111 | -0.069 | 0.312* | 0.045 | -0.034 | -0.003 | 0.048 | -0.025 |
| KLAC | | | | | | | | | | | | | 0.261 | 0.011 | -0.304* | -0.022 | -0.269 | -0.059 | -0.114 |
| ER | | | | | | | | | | | | | | 0.118 | 0.081 | -0.122 | 0.025 | 0.173 | 0.155 |
| ASV | | | | | | | | | | | | | | | 0.228 | -0.268 | 0.187 | 0.229 | 0.182 |
| AC | | | | | | | | | | | | | | | | 0.044 | 0.317* | 0.093 | -0.019 |
| GC | | | | | | | | | | | | | | | | | 0.129 | -0.119 | -0.143 |
| HL | | | | | | | | | | | | | | | | | | 0.595* | 0.264 |
| ML | | | | | | | | | | | | | | | | | | | 0.791* |
| HRR | | | | | | | | | | | | | | | | | | | |

* values denote significane at 5% level

**Table 7. Eigen values of the correlation matrix deduced for 16 variables**

| | Eigen Values of the Correlation Matrix | | | |
|---|---|---|---|---|
| | Eigen Value | Difference | Proportion | Cumulative |
| 1 | 3.06512862 | 0.36522576 | 0.1916 | 0.1916 |
| 2 | 2.69990286 | 0.95432561 | 0.1687 | 0.3603 |
| 3 | 1.74557725 | 0.13762996 | 0.1091 | 0.4694 |
| 4 | 1.60794729 | 0.28967657 | 0.1005 | 0.5699 |
| 5 | 1.31827071 | 0.16953303 | 0.0824 | 0.6523 |
| 6 | 1.14873768 | 0.08329421 | 0.0718 | 0.7241 |
| 7 | 1.06544348 | 0.25759360 | 0.0666 | 0.7907 |
| 8 | 0.80784987 | 0.06251302 | 0.0505 | 0.8412 |
| 9 | 0.74533685 | 0.18909656 | 0.0466 | 0.8878 |
| 10 | 0.55624028 | 0.09837642 | 0.0348 | 0.9225 |
| 11 | 0.45786386 | 0.12613647 | 0.0286 | 0.9511 |
| 12 | 0.33172739 | 0.10092477 | 0.0207 | 0.9719 |
| 13 | 0.23080263 | 0.09281185 | 0.0144 | 0.9863 |
| 14 | 0.13799077 | 0.07636523 | 0.0086 | 0.9949 |
| 15 | 0.06162554 | 0.04207063 | 0.0039 | 0.9988 |
| 16 | 0.01955492 | | 0.0012 | 1.0000 |

that seven principal components (PCs) have Eigen value > 1 which account for approximately 80% of the variability which indicate the contribution of many traits with higher level of correlation to explain the genetic variability in the rice collections (Table 7). First five PCs were employed for cluster analysis using UPGMA clustering which divided rice accessions in to five clusters (Fig. 1) and the mean values of the clusters have been shown in Table 8. Accessions of cluster I have lowest mean days to heading and maturity along with lowest yield per plant while cluster II members have highest days to heading and maturity. Cluster III comprised of entries having shortest plant height, heaviest grains, longest kernel length and kernel length after elongation while cluster IV have tallest plants, highest number of tillers, longest panicle length, highest water uptake and highest grain yield per plant. Entries of cluster V have lowest 1000 grain weight, short panicle length, shortest kernel length and highest elongation ratio. Cultivars in cluster IV like *Attey* and *Tulasi* are preferred due to tall height having good straw yield and relatively high grain yield but prone to lodging and take longer duration to mature. Hybridization of entries in cluster IV with elite high yielding medium to early duration lines/varieties may result in isolating superior segregants. Earliness is a preferable trait of cluster I, however improvement in grain yield can be made by crossing with high yielding varieties which perform better under organic conditions

**Table 8. Mean values of 16 characters for five clusters grouped based on UPGMA**

| Character | Cluster I | Cluster II | Cluster III | Cluster IV | Cluster V |
|---|---|---|---|---|---|
| Plant height (cm) | 135.00 | 133.84 | 121.33 | 149.25 | 125.83 |
| Days to 50% heading | 99.25 | 116.50 | 111.55 | 109.75 | 113.85 |
| Number of tillers | 9.30 | 11.36 | 9.76 | 13.90 | 9.68 |
| Panicle length (cm) | 25.04 | 25.02 | 24.95 | 26.50 | 24.71 |
| Days to maturity | 142.13 | 164.00 | 155.09 | 147.25 | 154.00 |
| Yield per plant (g) | 12.61 | 14.33 | 20.38 | 27.03 | 17.62 |
| 1000 grain weight (g) | 24.93 | 22.74 | 25.88 | 22.82 | 20.44 |
| Kernel length (mm) | 4.87 | 5.34 | 6.19 | 4.66 | 4.29 |
| Kernel breadth (mm) | 2.68 | 2.25 | 2.24 | 2.57 | 2.45 |
| Volume expansion ratio | 4.45 | 5.07 | 4.65 | 4.43 | 4.58 |
| Water uptake | 255.00 | 301.50 | 299.09 | 307.50 | 252.69 |
| Kernel length after elongation (mm) | 9.99 | 11.59 | 13.81 | 10.80 | 10.62 |
| Elongation ratio | 2.05 | 2.11 | 2.23 | 2.30 | 2.58 |
| Alkali spreading value | 5.75 | 6.90 | 6.73 | 6.75 | 6.85 |
| Amylose content (%) | 21.33 | 22.35 | 19.20 | 22.78 | 21.15 |
| Gel consistency | 57.13 | 48.30 | 48.55 | 51.88 | 47.62 |
| | Red zomu, Zomu, Kalodhan, Tabrey, Thulo attey, Takmaru, Marsee, Chirakey (8) | Chinidhan, Kataka, Sijali, Jhapaka, Sanokhamti, Khimti, Khamti, Brihmphool, Charinangrey, Musuli (10) | Nepaldhan, Phouryal, Lalbacchi, Charimasini, Champey, Zornalli, Dhoodkalam, Kalsati, Anandhi, Dhutraj, Japani (11) | Tauli, Kaleybungey Bhangeri, Tulasi, Attey Dudheyjuari, Phoolpatta, Yeidehi (8) | Timburey, Ramzeera, Rambhog, Ramsaree, Baelbutty, Krishnabhog, Kalonunia, Sanoattey, Katti, Taichung, Pahelodalle, Takmaru (LL), Zokub (13) |

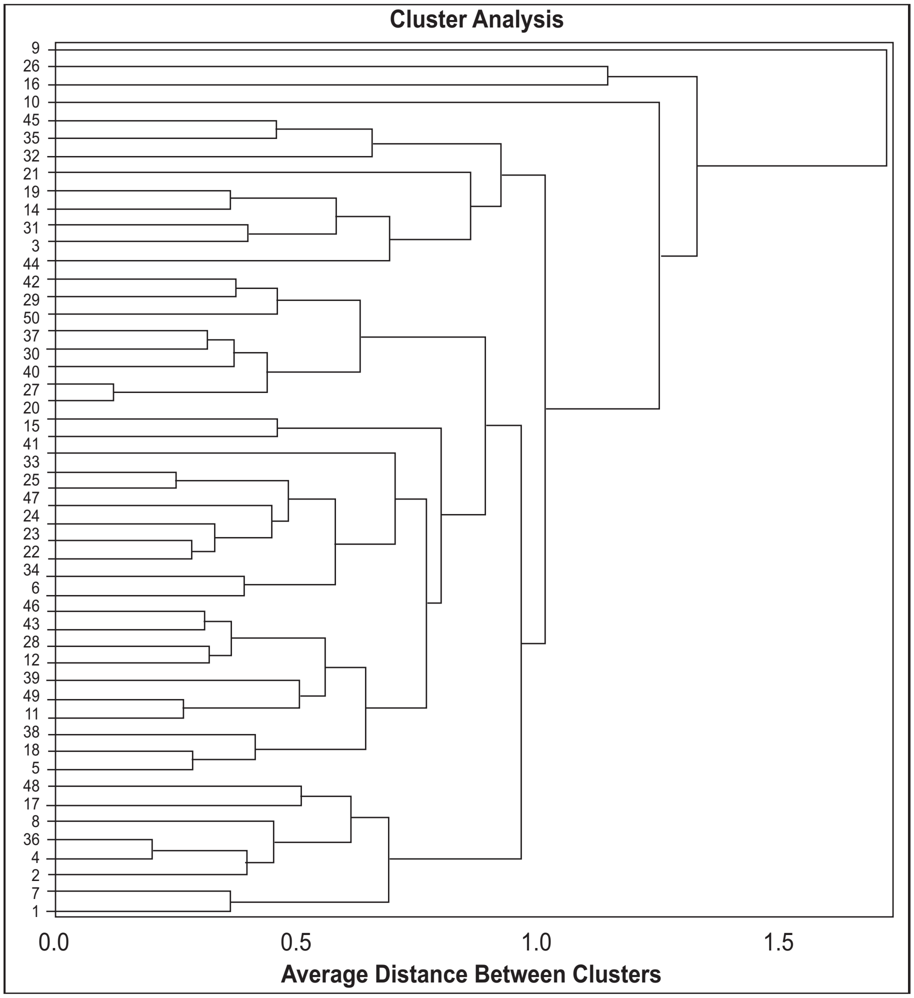


**Fig. 1. UPGMA based clustering of rice germplasm based on five principal components**

likewise entries in cluster III have better plant type for high yield but needs improvement in number of effective tillers and higher number of filled grains per panicle. Characters having maximum value for PC1 are days to maturity, days to heading and KLAC while kernel breadth contributed negatively towards first PC. Variables highly and positively correlated for PC2 were amylose content and plant height while seed weight and kernel length contributed negatively towards PC2. First component differentiated those accessions having long flowering and maturity duration alongwith minimum kernel breadth, hence PC1 identified mainly the phenological variables for differentiating the accessions while PC2 identified plant height and amylose content along with the grain parameters which contributed most negatively. Ahmed *et al*. (2016) reported first three PCs for 72.24% of the total variation among 10 agro-morphological traits and obtained seven cluster groups using UPGMA. They also found that first five PCs with vector value >1 for 82.90% of total variation and grouped 31 rice germplasm in to four clusters. These above findings are in line with Caldo *et al.* (1996) who reported maturity, heading and plant height among characters contributed to the parental lines of Philippines rice cultivars while Sharma *et al.* (2012) and Guei *et al.* (2005) reported negative contributions of phenological like days to flowering and maturity characters for PC1.

Maintaining landraces *ex-situ* is one of the best conservation strategies for genetic resources as marginal farmers prioritize reaping maximum production instead of maintaining genetic diversity (Lipton and Longhurst, 1989). The information generated during the present study is worthy of attention and could be utilized for conservation, utilization and improvement of local rice cultivars.

## Conclusions

Sikkim is one of the smallest states in India and the occurrence of tremendous variability in rice landrace germplasm within the small geographical area is indeed noteworthy with many of the landraces collected having not been reported in the past. The agro- morphological characterization unraveled important traits of immense value to the breeders having ample scope for improvement of popular landraces like *Attey*, *Kalonunia*, *Bhrimphool* and *Krishnabhog* for the economic benefit of local farmers. Due to their small population size, these landraces are prone to genetic erosion and oblivion without any benefit to local farmers. Therefore, registration of important landraces with Protection of Plant Varieties and Farmers Rights Authority under Farmers' Variety category by the biodiversity management committees may help the farming communities not only in protecting their varieties but also in accruing some royalties through access and benefit sharing mechanism.

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