RESEARCH ARTICLE

Genetic variability of panicle architecture in indigenous rice landraces of Koraput region of Eastern Ghats of India for crop improvement

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Abstract Panicle architecture is an important character that influence reproductive success and contributes directly to grain yield. In the present study, we evaluated diversity of panicle traits in 77 indigenous rice landraces from Koraput and compared with three popularity cultivated hybrid varieties of the locality for possibility of using in crop improvement program. Significant morphological variations of panicle traits such as panicle number, panicle angle, panicle weight, panicle length, grain number and grain weight were recorded in studied rice landraces. Based on the principal component analysis, first two axis of principal component captures 56.34% of the total variation and indicated significant variability of panicle traits among the genotypes. Panicle length, panicle weight, grain number and flag leaf area are the major determinants of phenotypic diversity. Multiple correlation between traits indicated that panicle weight in studied rice landraces were positively correlated with panicle number, grain number and leaf area and negatively associated with panicle length, panicle angle and chaff number. The genetic advance as percentage of mean (GAM) ranged from 22.19% for panicle length to 147.02% for panicle angle. High GAM along with heritability was observed for panicle number, panicle

weight, grain number and chaff number and are important traits for selection during crop improvement. Some of the landraces such as Matidhan, Bhatagurumukhi, Chiklakoli and Kamuntana remarkably showed superior panicle weight along with higher grain number and length of panicle, which can be used in the future rice breeding program.

Keywords Genotypic variation · Panicle phenotyping · Panicle traits · Rice landraces · Principal component analysis

Introduction

Rice (*Oryza sativa* L.) is an important food crops consumed by more than 50% of the world population (Scheben et al. 2016). The global demand for rice production in 2025 is 758 million tonnes, which is significantly higher than the present level of around 600 million tonnes (Nakano et al. 2019). The yield potential of rice needs to be increased to support the burgeoning human population, which can only be underpinned by an increase in grain number for increasing crop yield. Rice grain yield is a complex trait which is influenced by panicle size, arrangement of spikelet's, percent of filled spikelet and weight of grains (Mohapatra et al. 2011). The panicles and its associated traits are considered as most intuitive part of rice which regulates the quality and yield of rice (Lei et al. 2018; Wu et al. 2016). The panicle architecture is mainly characterized by panicle length, along with the arrangement of branches and grains (Xing and Zhang 2010; Okada et al. 2018). Panicle number is associated with the number of tillers and grain number with panicle branching, and the number of grains makes the largest contribution to grain

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productivity (Ikeda et al. 2013; Zhang and Yuan 2014; Huang et al. 2018). Panicle is the essential organ and its architecture is the major target in breeding program for improving grain number and yield (Mohapatra et al. 2011; Adriani et al. 2016; Lei et al. 2018). Many genes and QTLs have been identified that are linked with panicle architecture in rice (Ikeda et al. 2005; Fujishiro et al. 2018; Nakano et al. 2019). Moreover, identifying a donor with novel quantitative trait locus (QTL) that regulates panicle architecture would assist future rice improvement program (Wang et al. 2007; Zhou et al. 2014; Fujishiro et al. 2018; Nakano et al. 2019). Therefore, assessment of genotypic variations of panicle traits in different rice genotypes is an important requirement for an effective breeding program intending for superior grain yield in rice (Zhou et al. 2003; Zhao et al. 2016; Adriani et al. 2016). Compared with the wild and high yielding rice, relatively few information is published regarding the panicle phenotyping in indigenous rice genotypes. However, there is a paucity of information regarding the relationship between panicle traits and grain yield in traditional rice landraces.

Traditional/indigenous rice genotypes exhibit huge genetic diversity and reservoir for many potential genes and still remain untapped (Samal et al. 2018). These genotypes show many useful characters and are traditionally cultivated in local agro-ecological condition (Tripathy et al. 2005; Arunachalam et al. 2006). The introspection of such diversity is vital for reaching a consensus and taking decision on the conservation and proper utility in breeding program. Koraput region of Eastern Ghats of India, is a hotspot of indigenous rice diversity and secondary centre of origin of aus ecotype (Patra and Dhua 2003). Varied agroclimatic ecosystems of these region and varied topography with an altitude varying from 500 to 1600 mean sea level favors for rice diversity (Mishra et al. 2018). During 1955–1959, the Central Rice Research Institute (CRRI), Cuttack had collected 1745 germplasm accessions of cultivated rice and after 40 years in 1995–1996, NBPGR, New Delhi explored this region and collected only 318 accessions (Tripathy et al. 2005). In the present scenario, the genetic base of rice is declining continuously with increasing genetic vulnerability due to spread of modern high yielding varieties in this region. Recently, some scientific report highlighted the importance of the region and genetic potentiality of rice diversity in relation to different agronomic traits (Mishra et al. 2018, 2019; Panda et al. 2020). However, there is a dearth of information on panicle phenotyping in traditional rice landraces of Koraput. Therefore, the present study aims to evaluate the genetic diversity of panicle traits in indigenous rice genotypes of this region. Further, genetic variation, heritability and genetic advance of these landraces was studied for better understanding on the variability of the

population. The findings of the study will be useful for protection, conservation and rational use local germplasm in rice breeding program.

Materials and methods

Plant materials and experimental set up

Seventy-seven indigenous rice landraces of Koraput and three hybrid varieties (Kaberi, Raja and Sobhagya) popularly grown in the locality were selected for the study. The site of collection of traditional rice landraces are shown in Fig. 1. The details of the rice genotypes with their habitat and maturity duration are presented in Table 1.

The study was conducted during wet season of 2019 at the experimental field of MS Swaminathan Research Foundation, Jeypore (82° 44' 54" E to 18° 46' 47" N, 680 m altitude and 1500 mm rainfall). The soil of experimental field was deep loamy and lateritic soil with pH 06.20, 0.13 ppm of organic carbon, 0.16 ppm of nitrogen, 0.01 ppm of phosphorus, and 0.82 ppm potassium. Seed treatments were carried out by use of salt water, cow urine or cow milk before sowing for 24 h. Seeds of all the landraces were sown first in a nursery bed. The 20 days old seedlings were directly transplanted @ 2 seedlings per/hill in lines with 20 cm × 15 cm spacing. Organic fertilizers was added in the form of farmyard manure. Experimental field was regularly irrigated with running water and with $1260 \pm 40 \mu \text{mol m}^{-2} \text{s}^{-1}$ maximum photosynthetic photon flux density, $34.4 \pm 2^\circ \text{C}$ air temperature and 65–70% relative humidity during the growth period. The data recording was performed during maturity stage.

Measurement of panicle traits

The rice panicles were collected from the healthy plants after the maturity of grains during last week of December 2019. Three samples of each variety were taken. The panicles were cut down 1 cm below from the flag leaf by a sharp scissor during the time of collection. The panicle samples were photographed with the help of a DSLR camera after collection and bring to the laboratory for analysis of morphological study.

Number of panicles per hill of each sample determined by counting the total number of branches developed. Angle between flag leaf and panicle of each sample was determined by the use of a protractor during the time of collection. Flag leaf area was measured by taking leaf length and width of each sample by a scientific ruler and leaf area was calculated following formula [Leaf area (cm^2) = $0.67 \times \text{length} \times \text{width}$] of Yoshida et al. (1976). Length of panicle of each sample measured from 1 cm

Fig. 1 Map showing study site of Koraput district of Odisha where indigenous rice seeds were collected

down of flag leaf to the tip by a scientific ruler. The number of grains per panicle of each collected sample was measured by counting the total number of filled grains present in a panicle. Number of chaffs per panicle of each variety was analyzed by counting the unfilled grains present in a panicle. Dry weight of panicle of each variety was measured after oven drying the sample at 72 °C for 48 h of the collected sample with the use of digital electronic weighing balance. Grain weight was obtained by taking 100 healthy grains of each variety with the use of digital electronic weighing balance.

Measurement of genetic variability parameters

The genetic variability parameters such as genotypic variance (σ_G^2) and phenotypic variance (σ_P^2) was estimated as per Steel et al. (1997). Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were calculated in the formula given by Burton and Devane (1953). Broad sense of heritability (h_{bs}^2) was calculated according to the formula of Falconer and Mackay (1996). Genetic advance (GA) and genetic advance as percentage of the mean (GAM) was calculated following the formula of Johnson et al. (1955).

Statistical analysis

Different panicle traits were subjected to analysis of variance using CROPSTAT statistical software. Principal component analysis (PCA) of different traits were carried out to detect underlying sources of variability by PAST-3 (Palaeontological Statistics) software. The similarity index among different rice genotypes was determined via cluster analysis by Bray–Curtis similarity using PAST-3 software.

Results

Morphological variations of panicle traits

The morphological variation of panicles of different rice genotypes are shown in Fig. 2. The quantitative traits such as panicle number, panicle angle, panicle weight, panicle length and grain weight in studied rice landraces are presented in Table S1. Summary statistics of different panicle traits is shown in Table 2. The coefficient of variation (CV) of different panicle traits varied from 15.44 to 84.39% among the studied rice landraces. The highest coefficient of variation was observed in panicle angle of about 84.39% followed by number of chaffs (67.95%), number of grain (34.16%), panicle weight (32.93%), panicle number (31.24%), whereas lowest CV was observed in panicle length which accounts 15.44% (Table 2).

Table 1 List of indigenous rice landraces of Koraput used for the study with their habitat and maturity duration

No	Name of variety	Land type	Maturity duration (days)	No	Name of variety	Land type	Maturity duration (days)
1	Badadhan	LL	148	41	Kanei	LL	140
2	Badali	LL	135	42	Kasikadam	LL	146
3	Badalochei	LL	135–140	43	Kiskeri	LL	120–130
4	Bankei	LL	130–135	44	Korkoli	LL	135
5	Banskanthia	LL	130–135	45	Kosikamal	LL	125–130
6	Baramasi	LL	120	46	Kudekhamankada	ML	140
7	Basantichudi	LL	139	47	Kudeswar	LL	127
8	Basnimundi	LL	161	48	Kujadhan	LL	120–130
9	Bastabhoga	LL	150	49	Kuyerkuling	LL	140
10	Baunsaganthi	LL	140–145	50	Laxmipati	LL	160
11	Bedagurumukhi	LL	140	51	Loserdhan	LL	130–135
12	Bedamakada	LL	153	52	Machhakanta	LL	135–145
13	Bhandamasuri	LL	145	53	Mahulakunchi	UL	110–115
14	Bhtachudi	ML	130	54	Mala Goindi	LL	145–150
15	Bhatadhan	ML	110	55	Mandagandhei	LL	120
16	Bhatagunda	ML	132	56	Masuridhan	LL	120–130
17	Bhatagurumukhi	ML	135	57	Matichudi	UL	95–100
18	Bhatamali	ML	131	58	Matidhan	UL	100
19	Bididhan	UL	158	59	Merlo	ML	160
20	Bodhebaring	ML	135	60	Muktabali	ML	125–130
21	Chatiachudi	LL	130	61	Nababi	ML	158
22	Chiklakoli	UL	146	62	Nadiarasa	LL	147
23	Dhabakalikuji	LL	140–145	63	Ojan	LL	135
24	Dhobkuji	LL	150	64	Osaganthili	UL	120–130
25	Dokramecha	LL	139	65	Pathangada	LL	100
26	Dubraj	LL	135	66	Patrali	LL	135
27	Dudhamani	LL	130–135	67	Pokhia	LL	140
28	Gangabali	LL	130–135	68	Rangakhadika	LL	120–125
29	Haladi	LL	125–130	69	Ranicheteka	ML	135
30	Hirakhandi	LL	130–135	70	Sankarjeera	LL	150
31	IpsigetDhan	LL	120–130	71	Sorudaka	LL	130
32	Jakasaru	LL	145	72	Sunakhadika	LL	125–130
33	Jamukoli	LL	125–130	73	Sunaseri	LL	125–140
34	Jhili	ML	153	74	Tarmandhan	ML	135
35	Kalachudi	LL	153	75	Tikichudi	LL	120–125
36	Kaladhan	LL	135	76	Tikiramundi	LL	130–135
37	Kalama	LL	142	77	Tulsiganthi	ML	130–135
38	Kalamali	LL	125–130	78	Kaberi (Hybrid)	LL	115–120
39	Kamuntana	ML	140	79	Raja (Hybrid)	LL	135–140
40	Kanakchudi	ML	148	80	Soubhagya(Hybrid)	LL	120–125

LL lowland, ML medium land, UL upland

There was a significant ($P < 0.05$) difference of panicle number recorded in different rice genotypes. The range of panicle number varied from 2.50 to 16.5 with a variance of 4.77% among the studied traditional rice landraces. The landraces ‘Matidhana’ showed highest no of panicles

(16.5) and ‘Mahulakunchi’ showed lowest no of panicles (Table S1). The panicle angle significantly ($P < 0.05$) varied from 5° in ‘Masuridhana’ to 70° in ‘Kiskeri’ variety with a mean value of 17.06°. The panicle length significantly ($P < 0.05$) varied from 21.10 cm in ‘Raja’ (hybrid

Fig. 2 Morphological diversity of panicles in studied indigenous rice landraces of Koraput

variety) to 49 cm in ‘Kiskeri’ with a mean of 32.49 cm. The flag leaf area of studied landraces of Koraput showed a wide variation that ranged from 8.85 cm² (‘Raja’ hybrid) to 46.38 cm² in ‘Kamuntana’. Furthermore, panicle weight significantly ($P < 0.05$) varied from 1.46 to 6.77 g among the studied rice lines. The highest panicle weight was found in ‘Bhatagurumukhi’ and lowest in Kuyerkuling among studied genotypes. The number of grains, number of

chaffs and 100 grain weight showed ample range of variations (Table S1). The number of grains varied from 48 to 260 whereas number of chaffs varied from 2.5 to 142 among the studied rice landraces. ‘Chiklakoli’ variety had highest number of grains whereas ‘Mahulakunchi’ had highest number of chaffs around 142 numbers. Similarly, 100 grain weights of all studied landraces and hybrid varieties were analyzed. It has been found that 100 grain

Table 2 Summary statistics of different panicle traits in studied indigenous rice landraces of Koraput

Statistical parameters	Panicle number	Panicle angle	Leaf area (cm ⁻²)	Panicle length (cm)	Grain number	Chaff number	Panicle weight (g Panicle ⁻¹)	Grain weight (g 100 grain ⁻¹)
Number	80	80	80	80	80	80	80	80
Minimum	2.50	5.00	8.85	21.10	48.00	2.50	1.46	0.64
Maximum	16.50	70.00	46.38	49.00	260.00	142.00	6.77	3.26
Sum	559.00	1365.00	1861.89	2599.05	10,046.50	3268.50	274.81	170.54
Mean	6.99	17.06	23.27	32.49	125.58	40.86	3.44	2.13
SE	0.24	1.61	0.70	0.56	4.80	3.10	0.13	0.05
Variance	4.77	207.32	39.70	25.17	1839.82	770.81	1.28	0.23
SD	2.18	14.40	6.30	5.02	42.89	27.76	1.13	0.48
CV (%)	31.24	84.39	27.07	15.44	34.16	67.95	32.93	22.59
F value	2.61**	6.48**	1.93**	3.31**	2.76**	3.05**	2.29**	7.54**

**Significance at 0.01 level of probability

weight ranges from 0.64 to 3.26 g 100 seed⁻¹ and the mean value of about 2.13 g 100 seed⁻¹ was observed (Table 2).

Genetic variability of panicle traits

The genetic variability parameters of different panicle traits are presented in Table 3. The phenotypic variation (σ_p^2) was more than genotypic variance (σ_G^2) in all the studied parameters. Similarly, the PCV was higher than GCV and ECV and lower difference was found among them in all the examined parameters (Table 3). The highest PCV value was recorded for panicle angle 84.40% followed by chaff number (59.43) and grain number (34.01) and panicle length showed lowest PCV value of 15.44%. The GCV (%) ranged from 12.89 to 77.61 and the panicle angle (77.61%) showed the highest GCV (Table 3). The broad sense of heritability ranged from 48.24% (leaf area) to 86.75% (grain weight) in different landraces. The value of GAM

ranged from 22.19 to 147.02% and the highest GAM was observed for panicle angle (147.02%), followed by chaff number (82.28%) grain number (44.64%) and panicle number (40.03) (Table 3).

Principal component analysis

Genotypic variations of panicle traits were studied by principal component analysis (Table 4; Fig. 3). Three principal components (PC) showing Eigen value more than 1 and in PC1 the highest variation was observed in leaf area (0.466) followed by grain number (0.465) and panicle length (0.457), whereas in PC2 accounts highest positive loading of 0.544 was observed in panicle weight followed by grain weight (0.488) and number of grain (0.399) (Table 4). The first two axis of principal component analysis captures 56.34% of the total variation (Fig. 3). The scatter plot between PC1 and PC2 showed a clear pattern of

Table 3 Genetic variability parameters such as range, mean, standard error (SE), genotypic variation (σ_G^2), phenotypic variation (σ_p^2), environmental coefficient of variation (ECV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV),

heritability in broad sense (h_{bs}^2), genetic advance (GA) and genetic advance as percentage of the mean (GAM) for different traits in indigenous rice landraces of Koraput, Odisha

Parameters	Range	Mean $\pm$ SE	σ_G^2	σ_p^2	ECV (%)	GCV (%)	PCV (%)	h_{bs}^2 (%)	GA	GAM
Panicle number	2.50–16.50	6.99 $\pm$ 0.24	2.97	4.77	27.14	24.63	31.23	62.22	2.80	40.03
Panicle angle	5.90–70.00	17.06 $\pm$ 1.61	175.30	207.30	46.89	77.61	84.40	84.56	25.08	147.02
Leaf area	8.85–46.38	23.27 $\pm$ 0.70	19.15	39.70	27.55	18.81	27.08	48.24	6.26	26.91
Panicle length	21.10–49.00	32.49 $\pm$ 0.56	17.55	25.15	12.00	12.89	15.44	69.78	7.21	22.19
Grain number	48.00–260.0	125.58 $\pm$ 4.80	1162.50	1824.60	28.98	27.15	34.01	63.71	56.06	44.64
Chaff number	2.50–142.00	40.86 $\pm$ 3.10	396.35	589.75	48.13	48.72	59.43	67.21	33.62	82.28
Panicle weight	1.46–6.77	3.44 $\pm$ 0.13	0.72	1.28	30.63	24.67	32.82	56.47	1.31	38.18
100 grain weight	0.64–3.26	2.13 $\pm$ 0.05	0.20	0.23	11.69	21.15	22.71	86.75	0.86	40.59

Correlation between initial variables with principal component and component loading

Table 4 Principal component analysis (PCA) of different morphological traits in studied rice genotypes

Parameters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Panicle number	0.009	0.160	0.879	0.073	0.366	0.245	0.056	0.000
Panicle angle	0.236	− 0.328	− 0.005	0.832	0.102	− 0.238	0.269	− 0.072
Leaf area	0.466	0.213	− 0.052	− 0.044	0.428	− 0.466	− 0.575	0.052
Panicle length	0.457	− 0.247	0.032	0.147	− 0.341	0.603	− 0.468	0.095
Grain number	0.465	0.309	0.135	− 0.103	− 0.382	− 0.194	0.410	0.556
Chaff number	0.323	− 0.362	− 0.258	− 0.331	0.578	0.297	0.379	0.153
Panicle weight	0.355	0.544	− 0.180	0.047	− 0.016	0.233	0.242	− 0.655
100 grain weight	− 0.267	0.488	− 0.328	0.396	0.278	0.351	− 0.071	0.470
Eigen value	2.773	1.755	1.078	0.873	0.696	0.400	0.301	0.125

Fig. 3 The principal component analysis (PCA) of studied indigenous rice landraces showing the genotypic relationship in a graphical representation (scatter plot) on the basis of different panicle traits

grouping of indigenous rice genotypes of Koraput with respect to panicle traits. Based on biplot, 19 indigenous rice landraces are grouped in one quarter and effectively separated from the other on the basis of panicle angle, panicle length and chaff number. However, 20 landraces are present in other quarter and separated from the other on the basis of traits such as panicle weight, number of grain and leaf area. Largest number of genotypes (23) separated from the other on the basis of grain weight (Fig. 3).

Relationship among different panicle traits in traditional rice landraces

Relationship among panicle traits in studied rice landraces were shown in Fig. 4. Based on multiple correlation analysis, panicle weight and grain weight in studied rice landraces were positively correlated with panicle number, grain number and leaf area and negatively associated with panicle length, panicle angle and chaff number. Further,

based on the person's correlation coefficient panicle weight showed significant positive relationship with leaf area ($r = 0.576^{**}$), panicle length ($r = 0.233^{*}$) and number of grains ($r = 0.693^{**}$) and chaffs number ($r = 0.361^{*}$). Grain weight is significant positive relationship with panicle weight ($r = 0.268^{*}$) and negatively associated with panicle length ($r = -0.476^{**}$), number of grain ($r = -0.240^{*}$) and chaffs of panicle ($r = -0.418^{**}$).

Cluster analysis of rice landraces based on panicle traits

The relationship among 77 indigenous rice landraces and 3 hybrid varieties was analyzed by Bray–Curtis similarity index is shown in Fig. 5. Based on the variation in panicle traits, the cluster analysis separated the rice landraces into two major groups each having several subgroups. The largest cluster accounts 76 landraces, showed more than 75% similarity, whereas the second major cluster had 3 rice

productive but it provides livelihood and nutritional security of poor farming communities due to their better agronomic traits (Panda et al. 2020). This is the first study on genotypic variability of panicle phenotyping in local indigenous rice germplasm of Koraput. The present study analyzed the panicle traits of 77 indigenous rice landraces of Koraput and also compared with three popularity cultivated hybrid varieties of the locality. Based on the analysis of variance, ample variation of panicle traits such as panicle number, panicle angle, panicle weight, panicle length and grain weight were observed among the studied rice landraces. Results indicated that overall high coefficient of variation was present for all the traits under study. Although morphological traits represent the results of the interaction between gene and the environment but the presence of a wide range of variability might be due to natural recombination and mutations that has accumulated over times in these landraces. Thus, there is a good opportunity to select better parental types improving panicle traits.

The panicle architecture such as panicle structure, size and panicle number are major components that determines yield of rice (Adriani et al. 2016; Lei et al. 2018). Results indicated a wide range of genotypic variation of panicle traits among the studied rice landraces. Rice landraces such as Matidhana, Bhatagurumukhi, and Chiklakoli showed superior panicle number, panicle weight and grain number respectively as compared to hybrid varieties and other genotypes. It has also been reported that number of panicles was relatively higher in *indica* cultivars than that of *japonica* cultivar (Ashikari et al. 2005; Nakano et al. 2017). Compact arrangement of spikelets within the panicle and absence of apical dominance were anticipated to be responsible for poor grain filling in rice (Mohapatra et al. 2011). Panicle angle and length of panicle are crucial for number of grain and crucial for compact arrangement of panicle (Wang et al. 2008). Indigenous rice landraces Kiskeri showed maximum panicle length and angle in compared to other genotypes which indicates superiority of panicle traits. Remarkable variation of flag leaf area was observed among studied rice landraces and maximum leaf area recorded in Kamuntana compared to other genotypes. Yoshinaga et al. (2013), suggesting that higher leaf area might be able to translocate photosynthetic products more efficiently to the panicle and helpful for better panicle growth and grain number. These findings of variations of panicle traits in the present study were also consistent with the earlier report of Kam fragrant glutinous rice (Lei et al. 2018), traditional rice landraces of Assam (Lahkar and Tanti 2017) and rice diversity of global collections (Ashfaq et al. 2012). Yield of rice grain is considered as important polygenic traits influenced by many phenotypic characteristics as well as environmental factors (Nakano et al. 2017).

To know the major contributing factor for grain yield, multiple correlation analysis was carried out among different panicle traits in studied rice genotypes. Results indicated that panicle weight in studied rice landraces were positively correlated with panicle number, grain number and leaf area and negatively associated with panicle length, panicle angle and chaff number. The observed variation of grain weight in studied rice genotypes were not based on panicle angle, flag leaf area, but related with grain number and chaff number as suggested earlier in different rice variety (Ashfaq et al. 2012; Tripathi et al. 2017).

Genetic variability analysis indicated that panicle number, panicle angle, panicle weight and chaff number are useful for selection of these traits in crop improvements as these traits showed high PCV and GCV value in the study. The value of GCV was lower than that of PCV and their differences were also low for the studied panicle traits. This indicates the studied traits were less influenced by environmental factor and genetic effects are more prevalent for phenotypic expression of panicle traits (Mohapatra et al. 2017). Similar findings are also reported earlier in different rice genotypes (Sahu et al. 2017; Tripathi et al. 2017). It has also been reported that high value of heritability and genetic advance for a particular trait are less influenced by environmental factors and useful for crop improvement (Panes and Sukhumi 1995; Mishra et al. 2019). Based on the results, panicle number, panicle weight, panicle angle, grain number and chaff number would be beneficial traits in crop improvement program for selection.

The observed panicle traits in studied rice landraces were subjected to PCA to reveal patterns of genotypic variation and removes data redundancy in yield associated traits (Ray et al. 2013). It can be used to determine traits having great effect of genotypic variation (Gour et al. 2017). The first two axis of principal component analysis captures 56.34% of the total variation. The traits such as flag leaf area, grain number, panicle length, panicle weight are the key determinants of phenotypic variation among the studied genotypes. Based on the cluster analysis, the studied rice landraces were grouped into two major cluster and the largest cluster accounts majority of landraces i.e. 76 number and showed more than 75% similarity. It might be due to their similar ecotype and are collected from similar agro-ecological conditions. Three indigenous rice landraces such as Badadhan, Laxmipati and Melro were highest genetic similarity with hybrid variety Raja and Bhatachudi and Loserdhan are very close to hybrid varieties Sobhagya and Kaberi respectively. The result of phenotypic traits may provide a baseline information for conservation and rational use of indigenous rice landraces in rice breeding program.

Conclusion

In conclusion the studied rice genotypes possess substantial variability for different panicle traits. Among different parameters, panicle length, number of grain and leaf area are the key determinants of phenotypic diversity among the landraces. Some of the landraces such as Matidhan, Bhatagurumukhi, Chiklakoli and Kamuntana remarkably showed superior panicle weight along with higher grain number and length of panicle, which can be used in future rice breeding program. The findings also indicated that the panicle weight was not significantly influenced by panicle number and panicle angle but it regulated by length of panicle and number of grains. Among the trait's panicle number, panicle weight, panicle angle, grain number and chaff number are valuable for breeding and can be used for direct selection in crop improvement. Further genetic diversity in terms of molecular assessment is necessary for using these genotypes in rice breeding program.

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Author's contribution D.P. and N.S. designed the experiments; K.L. cultivated the plants. N.S., P.K.B. and K.L. performed the measurement of panicle traits. D.P. analyzed the data and wrote the paper. All authors read and provided helpful discussions for the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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