Eco. Env. & Cons. 28 (May Suppl. Issue) : 2022; pp. (S261-S270)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i03s.039

Phenotypic characterization of aromatic rice (*Oryza sativa* L.) landraces of Odisha, India

Chinmayee Sahoo[1], Hatanath Subudhi[2] and Bhabatarini Panda[1*]

[1]Department of Botany, Utkal University, Vani Vihar, Bhubaneswar 751 004, Odisha, India
[2]National Rice Research Institute, Cuttack 753 006, Odisha, India

(Received 25 September, 2021; Accepted 26 October, 2021)

ABSTRACT

A total of 127 accessions of aromatic short grain rice were collected with detailed passport information from 30 districts of Odisha, India. The agro-morphological characters of all the landraces wererecorded according to Distinctiveness, Uniformity and Stability (DUS) guidelines with 21 qualitative and 16 quantitative characters and statistically analysed. Out of the different qualitative traits studied, ligule colour, panicle type, secondary branching, panicle axis and awning were found to be dimorphic; blade colour, blade pubescence, basal leaf sheath colour, collar colour, auricle colour, internode colour, culm strength, panicle exsertion, sterile lemma colour and stigma colour were trimorphic; leaf angle, culm angle, flag leaf angle, apiculus colour and lemma palea colour were tetramorphic. Variations were observed for all the qualitative traits except the presence of collar, auricles, and split shaped ligule among the accessions. The highest frequency was observed for panicle architecture; the presence of secondary branching (96%) and drooping type of panicle axis (95.3%).The weight of 1000 grain wt. which is a key character for selecting high yield variety, varied from 11.86g (Ranimasuri) to 23.09g (Kalkati). Similarly, panicle weight varied from 1.42g (Siresa) to 3.7g (Tulasiphool). The days to 50% flowering varied from 85.5 (Basumati) to 131 (Basauoga) with a mean of 111.17 days indicating that they are mostly medium to late flowering landraces. High grain yield landraces are Basapatri2, Basumati, Kalkatia, Tulasibas. These landraces may be popularized among the farmers and the same may be used in hybridization programmes for varietal development.

Key words *: Agro-morphology, Characterization, Frequency distribution, Aromatic short grain rice, Distinctiveness, Uniformity and Stability (DUS)*

Introduction

Rice (*Oryza sativa* L.) is the second-largest staple food for half of the world's population (Pathak *et al*., 2018) whereas, in India, it is the staple food for about 70% of people and is grown in 44.6 Mha area. Further, the country has a high diversity of rice germplasm which is distributed in different traditional rice-growing pockets. These include high yielding varieties as well as indigenous varieties with some special qualities which are confined to a few particular areas only. Due to the spread of high yielding varieties, the local landraces including aromatic rice are becoming extinct. Basmati, the popular aromatic rice of India is grown in Northwestern states like Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir and part of Uttar Pradesh with an average yield range from 2.5 to 3.0t/ha (Nene, 1998). Due to the distinct aroma,the basmati rice export is increasing every year,which resulted in a shortage for our internal consumption (Choudhury *et al*., 2003; Siddiq, 1990). Therefore, besides Basmati rice, large number of aromatic short grained rice varieties are becoming popular in different states

like Odisha, Chhattisgarh, West Bengal, Bihar, etc (Singh *et al*., 2000). These aromatic landraces possess the immense potential of most valuable genes; thus, exploration of such aromatic rice varieties will add value to the scientific community as well as consumers. Traditional cultivation of these aromatic rice is not soprofitable in Eastern India due to their low yield and long duration maturity traits, rather they are grown in specialized pockets for consumption on special occasions. Therefore, to uplift the economy of rice farmers, it is necessary to identify suitable genotypes, effective utilization of the crop germplasm and cultivation of high-priced rice or value-added rice varieties.

Geographically, Odisha constitutes the coastal belt as well as the Eastern Ghats of India, thus opening a huge window for different types of indigenous varieties of rice at different pockets. Odisha, being the secondary centre of origin of rice, is rich in rice genetic resources and having more than hundreds of short, slender aromatic rice varieties (Das, 2009; Richharia, 1979). A systematic study and characterization of these germplasms are essential in the present era for identifying the valuable genes for different traits, which can be manipulated for better yield and aroma and protecting the indigenous rice germplasm. Thus, there is a need to collect, explore, and evaluate the unexploited aromatic rice germplasm of Odisha.

Keeping this in view, an attempt was made here to collect the aromatic short grained rice from 30 districts of Odisha and evaluate them for their different yield characters based on agro-morphological characterization according to DUS test guidelines for popularization among farmers and promising entries to be used as donors for the varietal improvement program. Conservation of these valuable germplasms were also suggested for future generation to use.

Materials and Methods

Exploration and sample collection

Exploration and collection programs were undertaken under the auspices of the Department of Botany, Utkal University, Odisha, India during 2018 and 2019 (November –February). A total of 127 aromatic rice accessions were collected from 30 districts of Odisha, India (Figure 1). The seed samples were collected from the farmers' fields, farmyards or threshing floor with passport information and local information about the paddy variety from the farmers. The collected samples were grown in the field. The recommended agronomic practices were followed and necessary precautions were taken to maintain a uniform plant population of each genotype and to raise a good crop.

Agro-morphological characterization

Agro-morphological characterization of 128 landraces of rice was carried out using both qualitative and quantitative characters according to DUS and International Rice Research Institute-International Board for Plant Genetic Resources (IRRI-

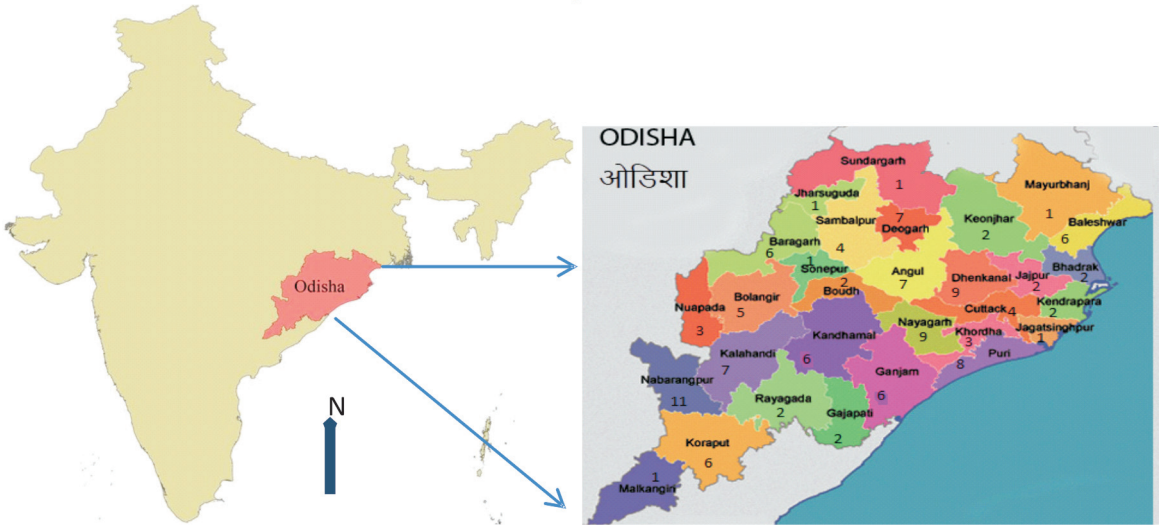


Fig. 1. Map of Odisha showing the location of exploration program.
*Number inside the figure represents rice landraces collected from different districts of Odisha, India.

IBPGR) guidelines (Anonymous, 1980). Data were recorded from randomly selected fiveplants in each replication at appropriate growth stages of crop. The 16 quantitative characters viz, leaf length (cm), leaf width (cm), ligule length (cm), plant height (cm), flag leaf length (cm), flag leaf width(cm), culm number, panicle length (cm), 1000 grain weight(g), panicle weight (g), grains/panicle, sterility percentage, grain length (mm), grain breadth (mm), days to 50% flowering and single plant yield(g) were observedin this study at different stages of growth to find out the distinctiveness, uniformity, stability among accessions and identifying promising genotypes for different yield contributing characters, which might be useful further for breeding purpose. Twenty-one qualitative characters were also observed through a visual assessment on a single plant basis according to the guidelines for DUS test in rice of PPV and FR Act 2001 (Sobha-Rani *et al*., 2006). Those characters were blade pubescence, blade colour, basal leaf sheath color, leaf angle, ligule colour, ligule shape, collar color, auricle color, culm angle, culm strength, flag leaf angle, secondary branching, panicle exsertion, panicle axis, awning, apiculus color, stigma color and lemmapalea color. The data were statistically analyzed following Gomez and Gomez (1984).

Results and Discussions

Morphological characterization is an important criterion to evaluate diversity among germplasms collected and to ensure effective utilization of the crop germplasm. In the present study, 127 aromatic rice landraces along with check Geetanjali were characterized for 37 agro-morphological characters (21 qualitative and 16 quantitative characters) to establish the distinctiveness, uniformity and stability among the landraces. The studied rice landraces displayed a wide range of variability for all the morphological traits considered here and similar results have been reported by Parikh *et al*. (2012); Rawte and Saxena (2018); Tirkey *et al*. (2013) for various aromatic rice landraces from India. It was observed that Basumati and Kalajeera are grown in most of the districts of Odisha. The landraces,such as Bishnubhog and Dubraj, are very popular among the growers of western Odisha from where the maximum number of aromatic landraces were collected. Although many of them have the same nomenclature, distinctive variability of the traits was observed among the landraces.

Qualitative characters

Qualitative characters were considered as morphological markers for agro-morphological characterization, as they are less influenced by environmental factors (Kalyan *et al*., 2017; Rao *et al*.,2013). Twenty-one agro-morphological parameters were assessed under this study at different stages of crop growth. Frequency distributions for all the characters under study were computed and presented in Table 1. Rice genotypes were characterized for various leaf traits at late vegetative or early flowering stages and variations were observed among all the landraces. The maximum frequency for leaf blade pubescence was recorded as the intermediate character (50.7%), followed by 37.5% showed pubescent, whereas, only 11.7% showed glabrous. The blade color showed the different intensity of green; 50.7% had pale green colour, 42.9% had medium green while 6.3% showed dark green colouration. Similarly, for basal leaf sheath color, 89% of landraces showed green, 6.3% showed light purple and only 4.7% showed purple color. Basal leaf sheath color, an important character for primary grouping of genotypes, was found to be purple for landraces like Kalajeera, Tulasi, Kalanunia and Ganjam local-1. The leaf angle in the majority of genotypes was either horizontal (42.2%)or droopy (39.8%). All the landraces were recorded with split-shaped ligule with 93.7%having white and 6.3% with purple line ligule. All the 128 accessions exhibited the presence of leaf ligule, collar and leaf auricles. More interestingly, the shape of the ligule was found to be split type in all the accessions without any variations. Our results are in close agreement with those of Rawte and Saxena (2018); Subudhi *et al*. (2012) where no variations were observed for the ligule shape among the accessions reported. Another study by Rawte *et al.* (2017) had also reported 94% of landraces with the split shape of ligule and 6% with acute types while studying the rice genotypes from Chhattisgarh, India. Collar colour and auricle colour were observed to be pale green in the majority of genotypes. Similarly, for internode colour, 70.3% exhibited light gold, 21.8% light green and 7.8% landraces exhibited green colour. Culm attitude is considered to bea good indicator of the growth habit of a particular species. During the current study, variation was observed among the landraces with respect to culm angle. Among them, 3.9% genotypes

Table 1. Frequency distribution of rice landraces for various DUS qualitative characters

Sl No.	Trait name	Variable	No. of Genotypes	Frequency (%)
1	Blade pubescence	1. Glabrous	15	11.7
		2. Intermediate	65	50.7
		3. Pubescent	48	37.5
2	Blade colour	1. Pale green	65	50.7
		2. Green	55	42.9
		3. Dark green	8	6.3
3	Basal leaf sheath colour (BLS)	1. Green	114	89
		2. Light Purple	8	6.25
		3. Purple line	0	0
		4. Purple	6	4.68
4	Leaf Angle	1. Erect	5	3.9
		2. Intermediate	18	14
		3. Horizontal	54	42.2
		4. Droopy	51	39.8
5	Ligule colour	1. White	120	93.7
		2. Purple line	8	6.25
		3. Purple	0	0
6	Ligule shape	1. Acute	0	0
		2. Split	128	100
		3. Truncate	0	0
7	Collar colour	1. Light green	95	74.2
		2. Green	25	19.5
		3. Purple	8	6.3
8	Auricle colour	1. Light green	100	78.1
		2. Green	20	15.6
		3. Purple	8	6.25
9	Culm angle	1. Erect	5	3.90
		2. Intermediate	40	31.25
		3. Open	60	46.87
		4. Spreading	23	17.9
10	Internode colour	1. Green	10	7.8
		2. Light green	28	21.8
		3. Light gold	90	70.3
		4. Purple	0	0
11	Culm strength	1. Strong	6	4.68
		3. Medium strong	0	0
		5. Intermediate	22	17.18
		7. Weak	100	78.12
		9. Very weak	0	0
12	Flag leaf angle	1. Erect	5	3.9
		3. Intermediate	28	21.8
		5. Horizontal	45	35.2
		7. Droopy	50	39.1
13	Panicle type	1. Compact	0	0
		3. Intermediate	107	83.6
		5. Open	21	16.4
14	Secondary branching	1. Absent	5	3.9
		9. Present	123	96
15	Panicle exertion	1. Well exserted	80	62.5
		3. Medium well exserted	42	32.8
		5. Just exserted	6	4.68
		7. Partially enclosed	0	0

Table 1. Frequency distribution of rice landraces for various DUS qualitative characters

Sl No.	Trait name	Variable	No. of Genotypes	Frequency (%)
16	Panicle axis	1. Straight	6	4.7
		9. Drooping	122	95.3
17	Awning	1. Present	10	7.8
		9. Absent	118	92.2
18	Apiculus colour	1. White	101	78.9
		2. Straw	8	6.3
		3. Brown	0	0
		4. Red	10	7.8
		5. Purple	9	7.0
19	Stigma colour	1. White	112	87.5
		2. Light green	0	0
		3. Yellow	0	0
		4. Light purple	10	7.8
		5. Purple	6	4.7
20	Sterile lemma colour	1. Straw	113	88.3
		2. Brown	10	7.8
		3. Red	0	0
		4. Purple	5	3.9
21	Lemma palea colour	Gold	108	84.3
		Brown furrow	8	6.3
		Black	5	3.9
		Brown spot	7	5.46

were found to have erect, 31.3% semi-erect attitude, 46.9% with open culm angle and 17.9% landraces were having spreading culm angle. Out of the 128 landraces evaluated, 100 were found to have weak culm strength. In case of the character flag leaf, the attitude of the blade in late observations was found to be mostly droopy (39.1%) and horizontal (35.2%) type whereas, 21.8% of landraces showed semi-erect type and 3.9% of landraces showed an erect type of flag leaf.

Panicle character is another important parameter used for crop yield measure, which was evaluated during the flowering stage of the plant growth. Panicles were found to be either intermediate types (83.6%) or open types (16.4%). Panicle exertion was either well exerted (62.5%) or medium well exerted (32.8%) in the majority of the varieties while only 4.7% were having just exerted including check Geetanjali. Secondary branching was observed in case of 96% genotypes and 95.3% were having drooping type panicle axis. Out of the 128 landraces, only 7.8% of accessions were recorded for the presence of awns, while the rest 92.2% were awnless. Dubraj, Sunkabasumati, Banspatri, Maharaji, Ramachandravoga and Basumati were found to have awns. The colour of awns was variable from yellowish white to light red and purple in some cases. In case of the colour ofthe sterile lemma, the frequency was highest for straw colour (88.3%) followed by brown (7.8%) and purple (3.9%). None of the landraces showed red coloured lemma. Similarly, for palea, it showed gold colour for 84.3% followed by brown furrow for 6.3%, brown spot for 5.5% and black for 3.9% of genotypes. Lemma palea colourwas brown furrow in case of Kalikati, brown in case of Imp Raskadam and Lalchandan and, black in case of Kalajeera and Tulasi. Grain type are short bold, mediumbold, medium slender and medium bold. Apiculus colour was white (78.9%) followed by red (7.8%), purple (7%) and straw coloured (6.3%). The trait stigma colour was observed as trimorphic; 87.5% accessions were having white stigma whereas, 7.8% and 4.7% showed light purple and purple colours respectively. Purple stigma was mostly recorded for Kalajeera, Tulasi and Ganjam local-1 accessions which made them distinct from other accessions. A similar finding was also reported by Kumar *et al*. (2016) where about 90% of accessions showed white stigma and only 10% showed purple stigma.

Quantitative characters

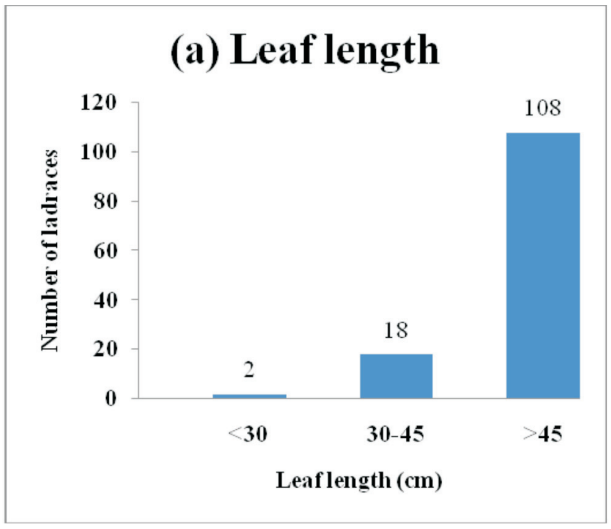
The statistical data viz., range, mean value, coefficient of variation and standard deviation of 16 quan-

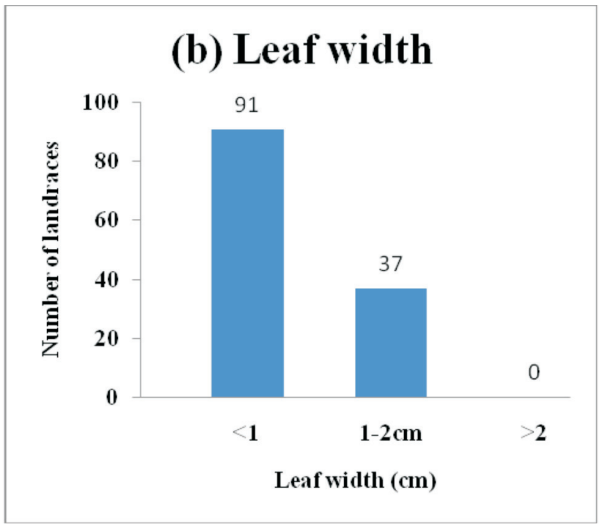
titative morphological characters for all the landraces are presented in Table 2. The frequency distributions for eachquantitative character are shown in Figure 2. In case of the leaf characters, the leaf length showed high variations and ranges from 29.87cm (Jabaphool) to 74.025 cm (Kapurkanti) with a mean value of 56.04 cm. Similarly, the leaf width varied from 0.42 cm (Kalajeera) to 1.57cm (Dubraj) with a mean of 0.85 cm showing mostly narrow (<1cm) leaves. The frequency distribution for leaf character revealed that, out of 128 landraces, 108 exhibited long leaf type (Fig. 2a), 91 landraces recorded narrow type of leaves (Fig. 2b) and 53 landraces were having ligule length more than 2.5cm (Fig. 2c). For the stem characters, the plant height varied from 67.6cm (Basumati-2) to 166.54 cm (Nanu) indicating wide variability having 30 very long and 21 short landraces (Fig. 2d). The number of culms ranged from 6.15 (Juiphula) to 16.15 (Basnaspuri) with CV value 25.42 and about 67.2% of accessions showed culm number between 10 to 14, whereas 12.5% showed culm number ranging between 14 to 18 (Fig. 2e). The panicle length was longest in Utkalballav (33.33cm) and shortest in Dhobaluchi (20.35cm) having 58.6% varieties with long and 13.3% with very long (>30 cm) panicle (Fig. 2f). Similarly, panicle weight varied from 1.42 g (Siresa) to 3.7 g (Thakurbhog) and grains per panicle varied from 72.5 (Govindbhog) to 232.5 (Bindli) with wide distribution among the landraces (Fig. 2g, h). Flag leaf, a very important character for yield enhancement, showed variation in length from 22.28 to 46.03cm and flag leaf width from 0.57 to 1.52cm indicating wide variability and frequency distributions (Fig. 2i, j). The weight of 1000 fully developed grains, another key character of high yield, ranged from 11.86g (Ranimasuri) to 23.09g (Kalkati) having frequency distribution in the range of low (62.5%), very low (27.7%) and medium (7.8%) grain weight (Fig. 2k) indicating apoor yield of the accessions. Joshi *et al*. (2007) noticed the variability for most of the morphological traits in 19 varieties of rice for their utility in varietal characterization and recommended thousand grains weight as a key trait for morphological characterization, since thenthis trait has been used by several researchers for characterizing rice varieties. For the grain characters, all the accessions showed either medium (1.6%), short (91.4%) or very short (7%) grain length (Fig. 2m) with very narrow (15.6%), narrow (82.8%) or medium (1.6%) grain width (Fig. 2n). Thus, all the landraces are having medium slender/short slender grains. The days to 50% flowering varied from 85.5 (Basumati) to 131 (Basavoga) with a mean of 111.17 days. Among them, 39.8% of landraces were of medium duration flowering variety (91-110 days), whereas, 2.3% of landraces were early type (71-90 days) and 57% of landraces were of late (110-130 days) 50% flowering type (Fig. 2o). Basapatri and Kalikati are found to have very good aroma. The co-

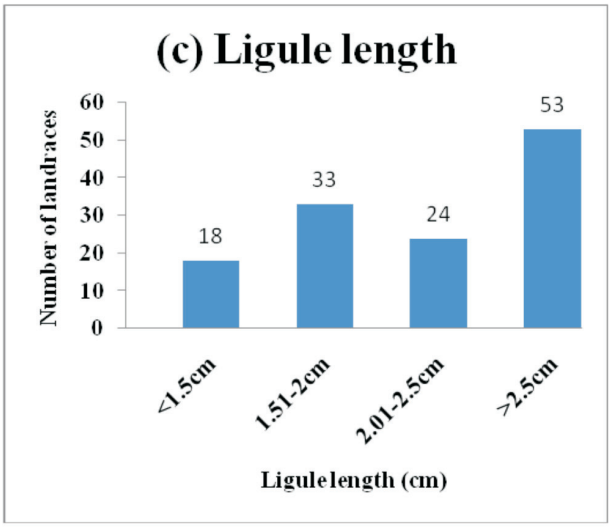
Table 2. Range, Mean, Coefficient of variation (CV) and Analysis of variance (mean square) of 16 yield attributing characters for 128 rice genotypes

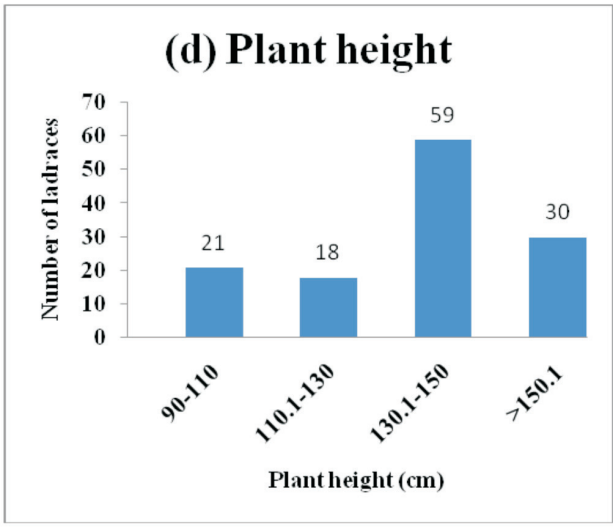
Character	Range	Mean ± SE	CV(%)	CD (5%)	Replicate	Treatment	Error
Leaf length(cm)	29.87-74.02	56.04±1.37	3.45	3.83	0.467	211.117*	3.74
Leaf width(cm)	0.42-1.57	0.84±0.06	10.11	0.16	0.001	0.121*	0.007
Ligule length(cm)	0.92-3.28	2.24±0.10	6.61	0.29	0.022	0.753*	0.021
Plant height(cm)	67.60-166.54	134.53±7.79	8.19	21.8	307.08	908.353*	121.403
Culm number	6.15-16.15	11.42±2.05	25.42	-	1.063	8.513*	8.440
Panicle length(cm)	20.35-33.33	26.75±1.14	6.05	3.2	4.526	17.568*	2.61
Flag leaf length(cm)	22.28-46.03	31.92±1.52	6.74	4.26	6.445	46.808*	4.63
Flag leaf width(cm)	0.57-1.52	1.14±0.06	7.39	0.16	0.047	0.107*	0.007
1000grain weigh(g)	11.86-23.09	16.51±0.89	7.61	2.48	0.052	11.127*	1.579
Panicle weight(g)	1.42-3.70	2.69±2.286	15.03	0.80	2.753	0.458*	0.164
Grains/panicle	72.50-232.50	159.23±9.19	8.16	25.70	52.562	1485.054*	168.956
Sterility%	6.24-28.90	14.14±1.66	16.56	4.63	50.347	34.988*	5.491
Grain length(mm)	5.50-9.90	6.66±0.28	5.90	0.77	0.292	0.640*	0.154
Grain breadth(mm)	1.64-2.75	2.11±0.12	8.08	0.33	1.158	0.056*	0.029
DFF(days)	85.50-131.00	111.17±0.96	1.22	2.68	0.062	229.310*	1.842
Single plant yield(g)	5.60-18.80	11.59±1.12	13.56	3.12	9.222	17.185*	2.486

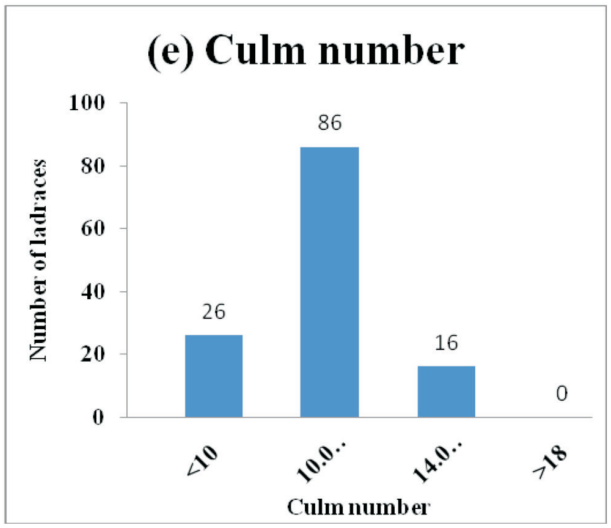
* Significant at 1% level

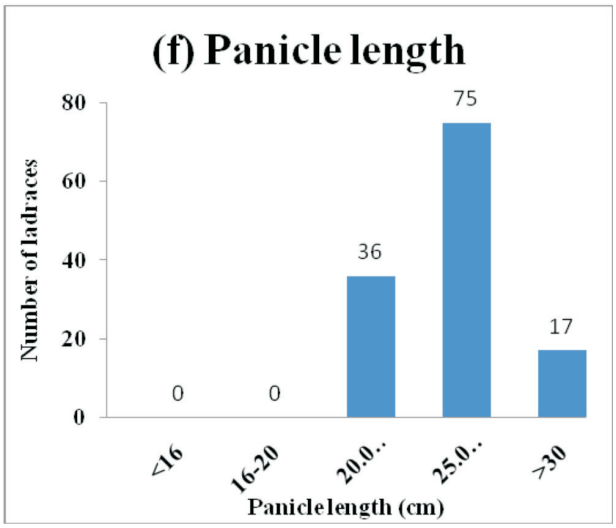

(a) Leaf length
Number of ladraces
120
100
80
60
40
20
0
2
18
108
<30
30-45
>45
Leaf length (cm)

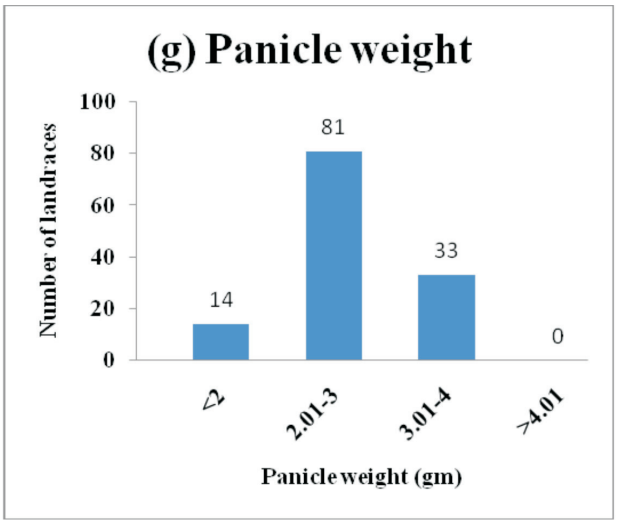

(b) Leaf width
Number of landraces
100
80
60
40
20
0
91
37
0
<1
1-2cm
>2
Leaf width (cm)

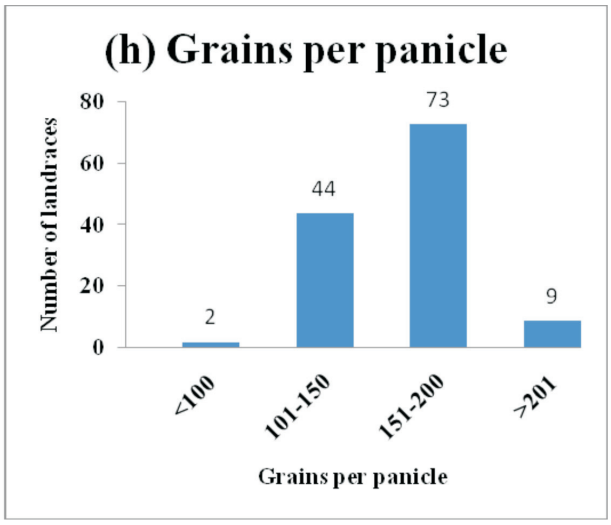

(c) Ligule length
Number of landraces
60
50
40
30
20
10
0
18
33
24
53
<1.5cm
1.51-2cm
2.01-2.5cm
>2.5cm
Ligule length (cm)

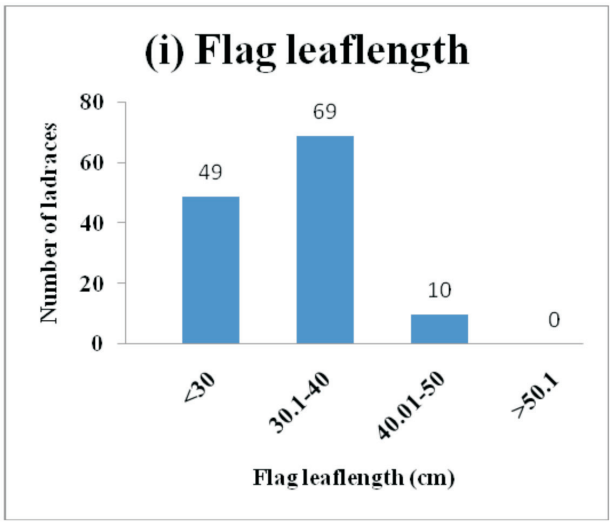

(d) Plant height
Number of ladraces
70
60
50
40
30
20
10
0
21
18
59
30
90-110
110.1-130
130.1-150
>150.1
Plant height (cm)

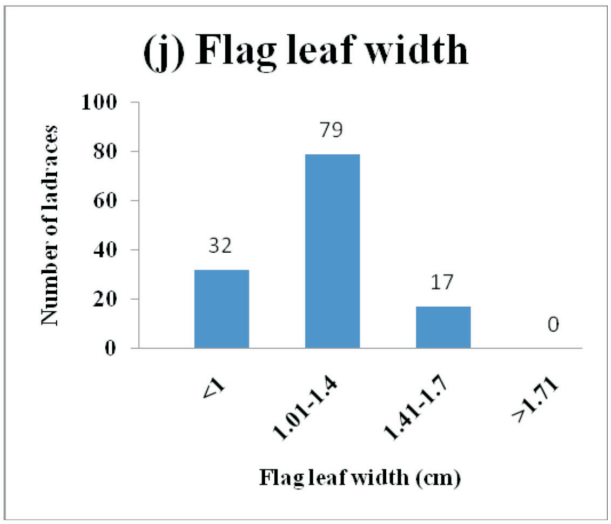

(e) Culm number
Number of ladraces
100
80
60
40
20
0
26
86
16
0
<10
10.0..
14.0..
>18
Culm number

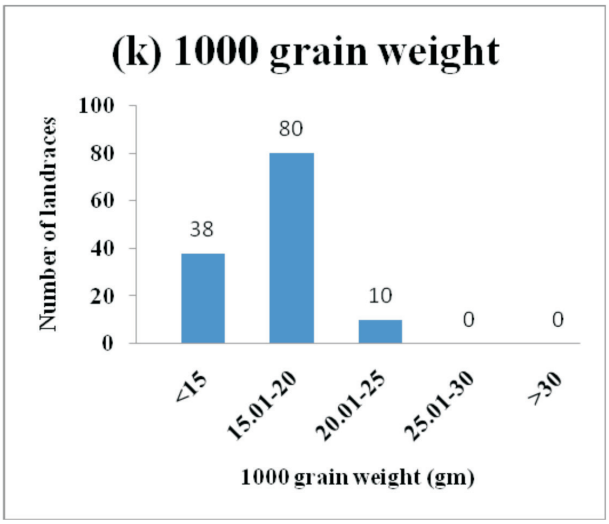

(f) Panicle length
Number of ladraces
80
60
40
20
0
0
0
36
75
17
<16
16-20
20.0..
25.0..
>30
Panicle length (cm)

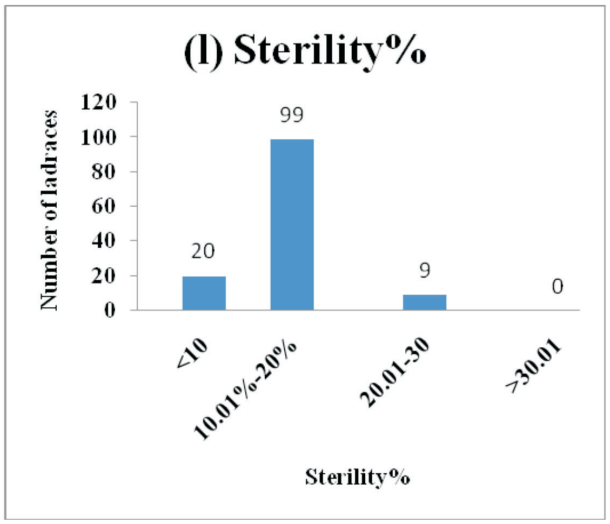

(g) Panicle weight
Number of landraces
100
80
60
40
20
0
14
81
33
0
<2
2.01-3
3.01-4
>4.01
Panicle weight (gm)


(h) Grains per panicle
Number of landraces
80
60
40
20
0
2
44
73
9
<100
101-150
151-200
>201
Grains per panicle


(i) Flag leaflength
Number of landraces
80
60
40
20
0
49
69
10
0
<30
30.1-40
40.01-50
>50.1
Flag leaflength (cm)


(j) Flag leaf width
Number of landraces
100
80
60
40
20
0
32
79
17
0
<1
1.01-1.4
1.41-1.7
>1.71
Flag leaf width (cm)


(k) 1000 grain weight
Number of landraces
100
80
60
40
20
0
38
80
10
0
0
<15
15.01-20
20.01-25
25.01-30
>30
1000 grain weight (gm)


(l) Sterility%
Number of landraces
120
100
80
60
40
20
0
20
99
9
0
<10
10.01%-20%
20.01-30
>30.01
Sterility%

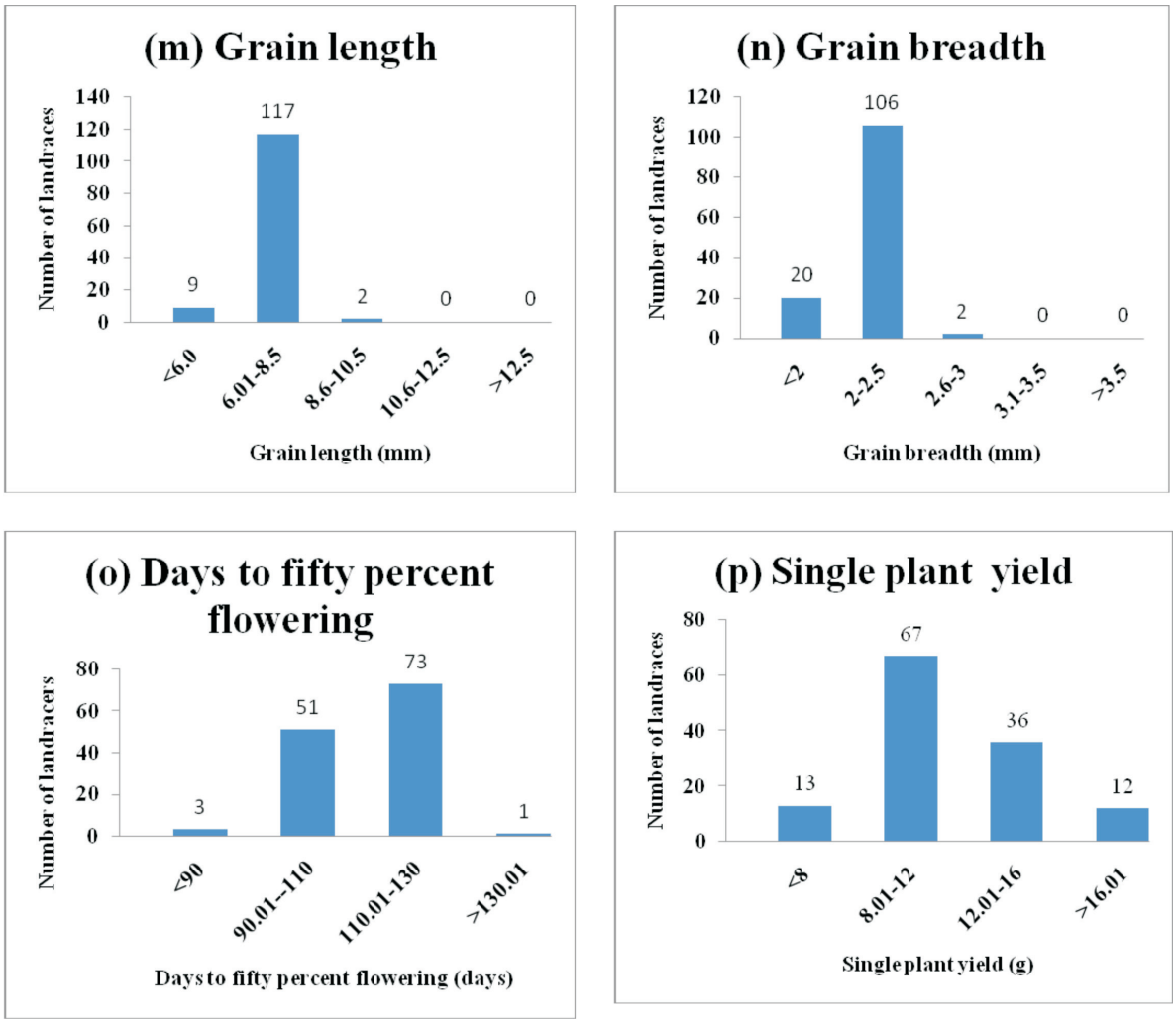


Fig. 2. Frequency distribution of DUS quantitative characters

efficient of variation was high in all the characters indicating wide diversity among the genotypes. The maximum value of the coefficient of variation was recorded for culm number (25.42%) followed by sterility percent (16.56%) and panicle weight (15.03%), indicating the presence of a high amount of variance and the role of the environment on the expression of these traits (Parikh *et al.*, 2012). Analysis of variance presented in Table 2exhibited the presence of significant difference among the genotypes for all characters and showed high variability. The genotypes differed significantly (P<0.01) for every character studied. Among the 127 accessions few genotypes such as Basapatri 2, Basumati, Gadakakudinga, Kalkatia, Tulasibas, Utkalballav etc. showed multiple yield attributing characters for Panicle length, Panicle weight, No. of grains per panicle, 1000gr.wt., single plant yield having higher values. These results of the grouping of germplasm will be helpful for future research programs, such as plant breeding and different varietal development processes. promising genotypes for different yield attributing characters

Conclusion

The present study revealed significant genetic variability among 127 landraces with respect to 21 qualitative and 16 quantitative traits. The wide range of variability observed in case of the characters evaluated may be attributed to the genetic diversity of the accessions at this study site. Therefore, the conservation of local biodiversity of such indigenous aro-

matic rice variety is essential in the present scenario. Out of the 127 accessions, Basapatri2, Basumati, Kalkatia, Tulasibas, Utkalballav etc. displayed as promising genotypes with different yield attributing characters, thus showing a window as a potential donor in hybridization programs. Therefore, this study will be useful for plant breeders, researchers and farmers to identify good genotypes for cultivation and used in varietal development programme and conservation of these genotypes will help to retain valuable gene for future.

Acknowledgement

The authors are thankful to the Department of Botany, Utkal University, Bhabaneswar, Odisha, India for providing facilities and also the local farmers for providing rice landraces used in the study.

Conflict of interest

The authors declare that there is no conflict of interest.

References

Anonymous, 1980. *IRRI-IBPGR Descriptors for rice* (*Oryza sativa* L.) IRRI, Philippines, 21.

Chaudhary, R.C. 2003. Specialityrices of the world: effect of WTO and IPR on its production trend and marketing. *J. Food Agric. Environ.* 1: 34-41.

Das, S.R. 2009. Indigenous aromatic rice: Native wealth of Orissa. *Emerg. Sci. J.* 1: 5-9.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research.* Intl. Rice Res. Inst. Philippines, John Wiley-Interscience Publication, p. 680.

Joshi, M.A., Sarao, N.K., Sharma, R.C., Singh, P. and Bharaj, T.S. 2007. Varietal characterization of rice (*Oryza sativa* L.) based on morphological descriptors. *Seed Res.* 35 : 188-193.

Kalyan, B., Radha-Krishna, K.V. and Subba-Rao, L.V. 2017. DUS characterization for germplasm of rice. *Int. J.Curr. Microbiol. App. Sci.* 6 : 3480-3487.

Kumar, V., Rastogi, N.K., Sarawgi, A.K., Chandraker, P., Singh, P.K. and Jena, B.K. 2016.Agro-morphological and quality characterization of indigenous and exotic aromatic rice (*Oryza sativa* L.) germplasm. *J. Nat. Appl. Sci.* 8 (1): 314-320.

Nene, Y.L. 1998. Basmati rice a distinct variety (cultivars) of the Indian subcontinents. *Asian. Agric. Hist.* 2 : 175-188.

Parikh, M., Motiramani, N.K., Rastogi, N.K. and Sharma, B. 2012. Agro-morphological characterization and assessment of variability in aromatic rice germplasm. *Bangladesh J.Agril. Res.* 37 (1): 1-8.

Pathak, H., Samal, P. and Shahid, M. 2018. Revitalizing Rice Production System for Enhancing Productivity, Profitability and Climate Resilience. In: Pathak, H., Nayak, A.K., Jena, M.N., Singh, N., Samal, P., Sharma, S.G. (Edited) *Rice research for enhancing productivity, profitability and climate resilience*. ICAR-National Rice Research Institute, Cuttack, Odisha, pp1-17.

Rao, Y., Yang, Y., Huang, L., Pan, J., Ma, B., Qian, Q. and Zeng, D. 2013. Research progress on cold stress in rice. *Mol. Plant. Breed.* 11: 443–450.

Rawte, S. and Saxena, R.R. 2018. Morphological characterization of selected rice (*Oryza sativa* L.) from core germplasm group of Chhattisgarh using DUS descriptors. *Int. J.Curr. Microbiol. App. Sci.* 7: 350-357.

Rawte, S., Saxena, R.R., Sahu, H. and Verulkar, S.B. 2017. Study of Agromorphological variation of rice (*Oryza sativa* L.) germplasm collected from different parts of Chhattisgarh. *Trend.Biosci.* 10(11) : 2078-2086.

Richharia, R.H. 1979. An aspect of genetic diversity in rice. *Oryza* 16 : 1-31.

Siddiq, E.A. 1990. Export prospects of Indian Basmati rice. *Ind. Farming.* 40 : 45-47.

Singh, R.K., Singh, U.S., Khush, G.S., Rohila, R., Singh, J.P., Singh, G. and Sekhar, K.S. 2000. Small and medium grained aromatic rice of India. In: Singh, R.K., Singh, U.S., Khush, G.S. (Edited) *Aromatic Rices;* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp 154-174.

Sobha-Rani, N., Subbarao, L.V. and Viraktamath, B.C. 2006. National guidelines for the conduct of tests for Distinctness, Uniformity and Stability: Rice (*Oryza sativa* L.) Directorate of Rice Research, Rajendra Nagar, Hyderabad, 1-39.

Subudhi, H.N., Samantaray, S., Swain, D. and Singh, O.N. 2012. Collection and agro-morphological characterization of aromatic short grain rice in eastern India. *Afr. J. Agric. Res.* 7(36) : 5060-5068.

Tirkey, A., Sarawgi, A.K. and Subbarao, L.V. 2013. Studies on genetic diversity in various qualitative and quantitative characters in rice germplasm. *Ind. J. Plant Gen. Res.* 26 : 132-137.