Original Research Article

Agro-morphological characterization for evaluation of potential upland red rice cultivars in Manipur, India

ABSTRACT

The present investigation was carried out during the two consecutive *kharif* seasons of 2020 and 2021 at Tamenglong district, Manipur. The aim of the research was to determine the high-yielding upland red rice cultivars in Manipur. The study materials consisted of twelve red rice cultivars that thrived in upland conditions, sourced from various districts in Manipur. The experiment was laid out in a randomised block design (RBD) with twelve cultivars and three replications. The soil of the experimental field was silty clay loam in nature, having an acidic reaction (pH 3.9), low in available nitrogen (237.96 kg/ha) and available phosphorus (14.8 kg/ha), medium in available potassium (263.66 kg/ha) and high in organic carbon (1.0%). The crop received a total rainfall of 2344.2 mm during the cropping season. The values of growth attributes such as plant height and LAI were found to be maximum in the cultivar Mariumiu kahengbo, and the number of tillers was found to be maximum in the cultivar Chatee. The number of effective tillers was found to be at its maximum in Chatee. The highest grain yield was recorded in the cultivar Chatee. The research findings recommend that farmers focus on cultivating the Chatee cultivar among the studied cultivars.

Keywords: Red rice, rainfed, growth, tillers, LAI, yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a major cereal crop around the world. Commercially, more than two thousand varieties of rice are grown throughout the world. In Manipur, rice covers an area of 189.87 thousand hectares, with a production of 445.55 thousand MT and a yield of 2.35 MT/ha [1]. Rice, the principal food of Manipur, is widely cultivated in the hills and valley areas of the state. Hundreds of indigenous aromatic rice cultivars are grown in localized pockets in several states. Rice is being cultivated in the hill zone of Manipur mostly during the *kharif* season as a rainfed crop in all situations, such as uplands, midlands and lowlands. Due to limited water resources, they might be thought to possess variable traits so as to survive a long spell of rainless weather and other desirable traits as well. It has been pointed out that the upland rice-growing regions of India represent a valuable centre for the conservation of indigenous rice [2]. Manipur is endowed with many varieties of rice. There are numerous unique rice cultivars with colour pigments, including black rice, red rice, and brown rice. Their name relates to the colour of the kernel (black, red, or purple), which is created by anthocyanin deposition in several layers of the seed coat, pericarp, and aleurone. The collection of the Central Rice Research Institute (CRRI), Cuttack, Orissa, of 2,960 entries, mainly from the eastern states of India, had a relatively higher number of red rice. Of the 20% colored rice, 17.40%, 3.44%, and 2.50% were red, purple, and brown rice, respectively. A survey conducted by the National Bureau of Plant Genetic Resources (NBPGR) from 1991 to 1998 recorded about 35% and 21% red rice varieties in Orissa and Manipur [3,4]. Pigmented rice (red and black rice) is widely known as enriched rice, which has a distinctive flavour and health benefits. The aim of the research was to determine the high-yielding upland red rice cultivars in Manipur. The findings will benefit farmers by helping them choose cultivars that offer higher yields, leading to better income. Additionally, this research will contribute to the preservation of potential upland rice cultivars.

2. MATERIAL AND METHODS

2.1. Sampling location and soil properties

The present investigation was carried out at Machengluang village, Tamenglong district, Manipur, during two consecutive kharif seasons in 2020 and 2021 and laid out in a randomized block design with three replications. It is located at 25^0 08' N latitude and 93^0 62' E longitude, at an altitude of 1137 m above mean sea level. The study material, local red rice cultivars, was collected from farmers in various hilly districts of Manipur. The average monthly rainfall received was 210.87mm in the year 2020 and 179.83mm in the year 2021. The highest amount of rainfall was received in the months of June in 2020 (365.7 mm) and August in 2021 (248.00 mm), and the lowest amount of rainfall was received in the month of

April in both the years 2020 (102.8 mm) and 2021 (54.8mm). The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 3.9), low in available N (237.96 N kg/ha) and available phosphorus (14.80 P2O5 kg/ha), medium in available potassium (263.66 K2O kg/ha), and high in organic carbon (1%).

2.2. *Physical and chemical soil analysis*

The soil texture was determined by the Bouyoucos Hydrometer method [5] after treating the soil with hydrogen peroxide. The pH of the experimental soil was determined with the digital pH meter using a soil-water suspension of 1:2.5, as described by Jackson [6]. The oxidizable organic carbon was determined using the wet-oxidation method (Walkley and Black) [7]. The available N content of the soil samples was determined using the alkaline potassium permanganate method, as described by Subbiah and Asija [8]. The available phosphorus content of the soil was determined by following Bray and Kurtz's method [9], and the available potassium was extracted from soil using neutral N ammonium acetate at 1:5 soil; the extract ratio and the concentration of potassium present in the extract were determined using a flame photometer [6].

2.3. *Statistical analysis*

All the data pertaining to the present investigation were computed for statistical analysis using Fischer's method of analysis of variance (ANOVA) and interpreted as outlined by Gomez and Gomez [10]. The interpretation of the data was, however, based on 5% probability levels. Critical difference values were calculated wherever the 'F' test was found to be significant, and the treatment means were compared following critical differences (CD), as suggested by Gomez and Gomez [10] for significance at the 5% probability level.

2.4. Study material and method

The study materials consisted of twelve red rice cultivars (C_1-Angah, C_2-Beng neng, C_3-Bujaro, C_4-Chadae, C_5-Cha neng, C_6-Chatee, C_7-Mariumiu kahengbo, C_8-Picharo, C_9-Shantan naphaeng, C_{10}-Tabnangsang, C_{11}-Taneng kahengbo and C_{12}-Thanga mahra) that thrived in upland conditions, sourced from various districts in Manipur. Plant height from five randomly selected plants was recorded at 30, 60, and 90 days after sowing (DAS) and at harvest from the ground surface to the tip of the uppermost leaves during the vegetative stage and to the tip of the longest panicle during the reproductive stage. The leaf area index is the ratio between leaf areas and ground area.

$$\text{LAI} = \frac{\text{Area of total number of leaves}}{\text{Ground area from which leaves sample are collected}}$$

3. RESULTS AND DISCUSSION

Plant height: The result reveals a consistent increase in plant height from 30 DAS until harvest across all cultivars, as shown in Table 1. The plant height increased rapidly until 90 DAS due to the active vegetative growth phase of the plant, and then it started to slow down when it reached the reproductive phase. Plant height is one of the most important growth parameters of any crop, as it determines or modifies yield-contributing characteristics and finally shapes the grain yield [11]. Red rice plants had lighter green leaves and a taller plant height than white rice [12]. Among the cultivars, the highest plant height was recorded in the cultivar Mariumiu kahengbo (C7) at 30 DAS (33.56 cm), 60 DAS (88.87 cm), 90 DAS (124.70 cm), and at harvest (162.19 cm), and it was significantly higher than the rest of the cultivars, indicating that Mariumiu kahengbo exhibited vigorous growth throughout the growth stages. This was followed by Chatee (C6), which gives a mean height of 32.87 cm (30 DAS), 86.07 cm (60 DAS), 122.60 cm (90 DAS), and 159.91 cm (harvest). The differences in plant height between the cultivars were mainly due to varietal variation. Sarkar [13] also recorded variable plant height due to varietal differences. This result was consistent with those of Khatun [14] and Das *et al*. [15], who observed variable plant height among rice varieties.

Total number of tillers and effective tillers per hill: The number of tillers per hill increased progressively from 30 DAS to harvest (Table 2). Among the different red rice cultivars studied, the cultivar Chatee (C6) exhibited the highest number of tillers per hill throughout the growth stages, indicating that Chatee has a higher tillering capacity. At 30 DAS, it had an average of 4.05 tillers per hill, which increased to 11.41 at 60 DAS, 15.73 at 90 DAS, and 18.08 at harvest. The highest number of effective tillers per hill (6.07) was recorded in the cultivar Chatee (C6), which was significantly higher than the rest of the cultivars studied. Tillering ability plays a vital role in determining rice grain yield. Among the various yield components, productive tillers are very important, as the final yield is mainly a function of the number of panicle-bearing tillers per unit area. Jisan et al. [16] concluded that variation in the number of tillers per hill might be due to varietal characteristics.

Leaf Area index (LAI): Overall leaf area per unit ground area is an essential measure of the plant's overall supply of photosynthates, which accumulate in the developing sink. The variation in LAI is an important physiological parameter that eventually determines crop yield because it influences the light interception by the crop canopy [17]. The LAI of rice increases as crop growth advances and reaches a maximum at about heading or flowering [18]. The development of the leaf area index reflected a sigmoid pattern of growth. Pooled data from Table 3 shows that the mean leaf area index increases progressively with the advance in crop age up to the 90^{th} day of crop growth; thereafter, it declines till the harvest of the crop, irrespective of different cultivars. The maximum leaf area index was recorded in the cultivar Mariumiu kahengbo (C7) in all the growth stages with a value of 0.88 at 30 DAS, 3.28 at 60 DAS, 4.85 at 90 DAS, and 4.13 at harvest, and it was significantly higher than the rest of the cultivars, indicating that Mariumiu kahengbo had a greater leaf area throughout the growth period.

Grain and straw yield (q/ha): Based on the analysis of the data from Table 4, it is evident that there were significant differences in grain yield among the different red rice cultivars that were investigated. The highest grain yield of 26.75 q/ha was achieved by the cultivar Chatee (C6), which was significantly superior to all the other cultivars included in the study. This indicates that Chatee (C6) performed exceptionally well, as observed from its better growth characteristics and yield attributes. The overall performance was found promising in the case of the cultivar Chatee at Tamenglong location. Varietal differences in grain yield were reported by Biswas *et al.* [19]. The genotypes that produced a higher number of effective tillers per hill and a higher number of grains per panicle also showed a higher grain yield in rice [15]. Yield differences due to varieties were recorded by Islam et al. [20] who observed variable grain yield among varieties. Grain yield is a function of the interplay of various yield components such as the number of productive tillers, spikelets per panicle, and thousand grain weights (Hassan *et al*.) [21]. A perusal of the data from Table 4 shows that straw yield differed significantly in both seasons among the different red rice cultivars under study. The maximum straw yield of 57.23 q/ha was recorded in the cultivar Mariumiu kahengbo (C7), which was significantly on par with the cultivar Chatee (C6) with a mean straw yield of 56.95 q/ha. It suggests that these two cultivars (Mariumiu kahengbo and Chatee) have favourable characteristics that promote higher straw production, like more plant height, leaf area, and weight of the plant. Straw yield differences due to varieties were also recorded by Hossain [22].

Harvest index (%): The harvest index is a vital character with physiological importance. It reflects translocation of alternative dry matter partitioning of a given genotype to the economic parts. The pooled data on the harvest index of red rice cultivars differed significantly. The cultivar Tabnangsang (C10) displayed the highest harvest index, recording a maximum value of 40.19%. This finding suggests that this cultivar has a relatively efficient conversion of biomass into harvested grain compared to the other cultivars. On the other hand, the cultivar Shantan naphaeng (C9) exhibited the lowest harvest index at 29.50%, followed by the cultivar Picharo (C8), which had a mean harvest index of 31.81%. These results suggest that these two cultivars had a less efficient conversion of biomass to harvested grain compared to the other cultivars studied. Jisan et al. [16] and Tyeb et al. [23] reported that variety has a significant influence on harvest index. Varieties did not follow any regular trend in the case of the harvest index. The result was supported by Sohel *et al.* [24].

Table 1. Plant height (cm) of different red rice cultivars recorded at 30 DAS, 60 DAS, 90 DAS and at harvest

	30 DAS			60 DAS			90 DAS			Harvest		
Cultivars	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
C_1- Angah	32.25	30.05	**31.15**	84.75	82.55	**83.65**	117.75	113.55	**115.65**	141.56	138.81	**140.19**
C_2- Beng Neng	27.11	24.91	**26.01**	72.44	70.14	**71.29**	103.87	99.37	**101.62**	133.39	130.46	**131.93**
C_3- Bujaro	27.05	24.95	**26.00**	65.75	63.65	**64.70**	101.45	97.35	**99.40**	132.44	129.79	**131.12**
C_4- Chadae	33.42	31.32	**32.37**	85.50	83.50	**84.50**	122.50	118.60	**120.55**	151.45	149.06	**150.25**
C_5- Cha Neng	27.21	25.11	**26.16**	77.25	75.15	**76.20**	111.25	107.55	**109.40**	135.41	133.26	**134.34**
C_6- Chatee	34.12	31.62	**32.87**	87.37	84.77	**86.07**	124.75	120.45	**122.60**	161.47	158.34	**159.91**
C_7- Mariumiu kahengbo	34.61	32.51	**33.56**	90.12	87.62	**88.87**	126.75	122.65	**124.70**	163.47	160.91	**162.19**
C_8- Picharo	27.01	24.81	**25.91**	64.25	61.85	**63.05**	99.25	95.45	**97.35**	120.59	118.13	**119.36**
C_9-Shantan naphaeng	27.12	25.12	**26.12**	76.37	74.37	**75.37**	109.50	105.60	**107.55**	134.14	132.08	**133.11**
C_{10}- Tabnangsang	29.61	27.21	**28.41**	78.12	75.72	**76.92**	113.75	109.55	**111.65**	138.52	135.72	**137.12**
C_{11}- Taneng kahengbo	30.11	28.01	**29.06**	82.34	80.24	**81.29**	115.25	110.55	**112.90**	139.53	136.19	**137.86**
C_{12}- Thanga mahra	27.01	24.71	**25.86**	59.75	57.45	**58.60**	91.75	86.85	**89.30**	113.37	110.05	**111.71**
SE d (±)	0.52	0.51	**0.10**	1.63	1.47	**0.14**	2.17	2.83	**0.26**	2.14	1.84	**0.30**
CD (P=0.05)	1.07	1.06	**0.20**	3.37	3.05	**0.28**	4.51	5.87	**0.51**	4.43	3.82	**0.59**
C.V (%)	2.13	2.26	**1.98**	2.59	2.41	**2.24**	2.39	3.23	**2.53**	1.89	1.66	**1.60**

**DAS-Days after sowing*

Table 2. Total number of tillers per hill of different red rice cultivars recorded at 30 DAS, 60 DAS, 90 DAS and at harvest

	30 DAS			60 DAS			90 DAS			HARVEST		
Cultivars	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
C_1- Angah	3.29	3.08	**3.19**	9.26	9.05	**9.16**	12.84	12.28	**12.56**	16.73	16.52	**16.63**
C_2- Beng Neng	2.54	2.32	**2.43**	6.27	6.05	**6.16**	10.24	10.20	**10.22**	12.54	12.32	**12.43**
C_3- Bujaro	2.67	2.43	**2.55**	7.73	7.49	**7.61**	11.23	11.06	**11.15**	15.62	15.38	**15.50**
C_4- Chadae	3.34	3.16	**3.25**	9.39	9.21	**9.30**	13.49	12.65	**13.07**	16.84	16.66	**16.75**
C_5- Cha Neng	2.48	2.33	**2.41**	5.49	5.34	**5.42**	9.25	9.27	**9.26**	11.18	11.03	**11.11**
C_6- Chatee	4.18	3.91	**4.05**	11.54	11.27	**11.41**	16.57	14.89	**15.73**	18.21	17.94	**18.08**
C_7- Mariumiu kahengbo	2.75	2.57	**2.66**	8.17	7.99	**8.08**	11.67	11.42	**11.55**	16.35	16.17	**16.26**
C_8- Picharo	3.87	3.55	**3.71**	10.49	10.17	**10.33**	15.46	14.09	**14.78**	17.66	17.34	**17.50**
C_9-Shantan naphaeng	3.56	3.41	**3.49**	10.18	10.03	**10.11**	14.23	13.17	**13.70**	17.25	17.10	**17.18**
C_{10}- Tabnangsang	3.49	3.25	**3.37**	9.64	9.40	**9.52**	14.02	13.03	**13.53**	17.14	16.90	**17.02**
C_{11}- Taneng kahengbo	2.81	2.56	**2.69**	8.28	8.03	**8.16**	12.59	12.05	**12.32**	16.49	16.24	**16.37**
C_{12}- Thanga mahra	2.61	2.42	**2.52**	7.64	7.45	**7.55**	10.79	10.68	**10.74**	14.32	14.13	**14.23**
SE d (±)	0.07	0.07	**0.04**	0.20	0.27	**0.04**	0.22	0.19	**0.39**	0.29	0.29	**0.04**
CD (P=0.05)	0.14	0.15	**0.07**	0.41	0.55	**0.08**	0.45	0.40	**0.79**	0.60	0.60	**0.07**
C.V (%)	2.69	3.12	**2.75**	2.77	3.87	**0.72**	2.11	1.96	**3.01**	2.24	2.25	**2.01**

**DAS-Days after sowing*

Table 3. Leaf area index of different red rice cultivars recorded at 30 DAS, 60 DAS, 90 DAS and at harvest

	30 DAS			60 DAS			90 DAS			HARVEST		
Cultivars	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
C_1- Angah	0.56	0.60	**0.58**	2.55	2.52	**2.53**	4.44	3.64	**4.04**	3.27	2.92	**3.10**
C_2- Beng Neng	0.59	0.62	**0.60**	2.63	2.51	**2.57**	4.78	3.81	**4.29**	3.48	3.01	**3.25**
C_3- Bujaro	0.63	0.67	**0.65**	2.15	2.13	**2.14**	4.20	3.56	**3.88**	3.24	2.98	**3.11**
C_4- Chadae	0.57	0.59	**0.58**	2.53	2.47	**2.50**	4.26	3.58	**3.92**	3.17	2.92	**3.04**
C_5- Cha Neng	0.65	0.69	**0.67**	2.95	2.93	**2.94**	4.82	4.11	**4.46**	3.60	3.36	**3.48**
C_6- Chatee	0.69	0.73	**0.71**	2.79	2.74	**2.77**	4.93	4.11	**4.52**	3.77	3.40	**3.58**
C_7- Mariumiu kahengbo	0.85	0.91	**0.88**	3.33	3.23	**3.28**	5.25	4.44	**4.85**	4.32	3.95	**4.13**
C_8- Picharo	0.75	0.79	**0.77**	2.67	2.65	**2.66**	4.55	3.94	**4.25**	3.53	3.31	**3.42**
C_9-Shantan naphaeng	0.81	0.87	**0.84**	2.79	2.76	**2.77**	4.97	4.30	**4.63**	3.89	3.63	**3.76**
C_{10}- Tabnangsang	0.56	0.58	**0.57**	2.46	2.47	**2.46**	4.30	3.53	**3.92**	3.18	2.84	**3.01**
C_{11}- Taneng kahengbo	0.65	0.70	**0.68**	2.88	2.86	**2.87**	4.86	3.92	**4.39**	3.68	3.20	**3.44**
C_{12}- Thanga mahra	0.44	0.46	**0.45**	1.94	1.91	**1.93**	3.73	2.90	**3.31**	2.74	2.29	**2.52**
SE d (±)	0.01	0.01	**0.01**	0.06	0.03	**0.03**	0.10	0.06	**0.08**	0.07	0.05	**0.07**
CD (P=0.05)	0.03	0.02	**0.02**	0.12	0.06	**0.06**	0.20	0.11	**0.16**	0.14	0.10	**0.13**
C.V (%)	2.58	1.93	**2.34**	2.64	1.45	**2.08**	2.58	1.77	**2.53**	2.33	1.78	**2.43**

**DAS-Days after sowing*

Table 4. Number of effective tillers, grain yield (q/ha), straw yield (q/ha) and harvest index (%) of different red rice cultivars

	Number of effective tillers per hill			Grain yield (q/ha)			Straw yield (q/ha)			Harvest index (%)		
Cultivars	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
C_1- Angah	5.08	4.86	**4.97**	22.68	21.15	**21.91**	44.26	42.83	**43.55**	37.36	36.17	**36.77**
C_2- Beng Neng	4.11	3.88	**4.00**	24.50	22.56	**23.53**	49.19	44.40	**46.80**	35.96	36.67	**36.32**
C_3- Bujaro	4.90	4.67	**4.79**	20.06	18.38	**19.22**	42.50	43.44	**42.97**	35.27	32.97	**34.12**
C_4- Chadae	5.39	5.13	**5.26**	18.86	17.40	**18.13**	43.09	44.32	**43.70**	33.67	31.43	**32.55**
C_5- Cha Neng	4.01	3.82	**3.92**	23.91	22.05	**22.98**	52.65	54.49	**53.57**	33.84	31.42	**32.63**
C_6- Chatee	6.18	5.96	**6.07**	27.66	25.85	**26.75**	60.60	58.62	**59.61**	33.59	32.97	**33.28**
C_7- Mariumiu kahengbo	4.95	4.71	**4.83**	25.62	23.99	**24.80**	75.75	74.15	**74.95**	27.25	26.48	**26.86**
C_8- Picharo	6.13	5.91	**6.02**	20.00	18.88	**19.44**	49.10	51.37	**50.24**	31.84	29.73	**30.79**
C_9-Shantan naphaeng	5.98	5.74	**5.86**	21.49	20.22	**20.85**	60.44	61.73	**61.08**	28.67	27.11	**27.89**
C_{10}- Tabnangsang	5.42	5.21	**5.32**	25.05	23.34	**24.20**	41.45	40.44	**40.95**	40.66	39.73	**40.19**
C_{11}- Taneng kahengbo	5.05	4.84	**4.95**	27.07	24.79	**25.93**	55.25	50.20	**52.73**	35.31	35.71	**35.51**
C_{12}- Thanga mahra	4.13	3.92	**4.03**	17.04	15.78	**16.41**	36.53	33.48	**35.00**	35.53	36.09	**35.81**
SE d (±)	0.10	0.11	**0.01**	0.64	0.68	**0.23**	0.71	0.73	**1.77**	0.66	0.83	**0.81**
CD (P=0.05)	0.21	0.23	**0.03**	1.34	1.41	**0.46**	1.46	1.52	**3.55**	1.37	1.73	**1.62**

**DAS-Days after sowing*

4. CONCLUSION

The cultivar Mariumiu kahengbo was found to have the highest values of growth attributes among the different red rice cultivars studied, including plant height (30 DAS (33.56 cm), 60 DAS (88.87 cm), 90 DAS (124.70 cm), and at harvest (162.19 cm) and LAI (0.88 at 30 DAS, 3.28 at 60 DAS, 4.85 at 90 DAS, and 4.13 at harvest). The maximum effective tillers (6.07) were recorded in the cultivar Chatee and the highest grain yield (26.75 q/ha) was recorded for the cultivar Chatee. The cultivar Tabnangsang (C10) displayed the highest harvest index (40.19%). This finding suggests that this cultivar has a relatively efficient conversion of biomass into harvested grain compared to the other cultivars. The research findings recommend that farmers focus on cultivating the Chatee cultivar among the studied varieties. This approach can lead to both optimal yield and the advantageous health effects associated with consuming red rice.

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