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Burhanuddin Asadi
Department of Seed Science and
Technology, University of
Agricultural Sciences, Bengaluru,
Karnataka, India

K Vishwanath
AICRP on Seed (Crops), UAS,
GKVK, Bengaluru, Karnataka,
India

Nagaraj Hullur
AICRP on Seed (Crops), UAS,
GKVK, Bengaluru, Karnataka,
India

N Lokeshwari
Department of Seed Science and
Technology, University of
Agricultural Sciences, Bengaluru,
Karnataka, India

AB Narayanareddy
AICRP on Seed (Crops), UAS,
GKVK, Bengaluru, Karnataka,
India

Basavaraja B
AICRP on Seed (Crops), UAS,
GKVK, Bengaluru, Karnataka,
India

Corresponding Author:

K Vishwanath
AICRP on Seed (Crops), UAS,
GKVK, Bengaluru, Karnataka,
India

Evaluation of crop performance of fortified and other Paddy (*Oryza sativa* L.) varieties under aerobic condition

Burhanuddin Asadi, K Vishwanath, Nagaraj Hullur, N Lokeshwari, AB Narayanareddy and Basavaraja B

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Abstract

The present study was conducted to evaluate the performance of fortified and conventional paddy (*Oryza sativa* L.) varieties under aerobic cultivation conditions at the University of Agricultural Sciences (UAS), GKVK, Bengaluru. Aerobic rice cultivation, an emerging water-saving production system, has gained importance due to increasing water scarcity and the need for sustainable rice production. The experiment, laid out in a randomized complete block design with fifteen varieties and three replications, aimed to evaluate yield attributes under reduced water conditions. Variety KMP-220 recorded the highest number of productive tillers (18.67) and seed setting percentage (95.22%), while MAS-946-1 had the longest panicles (30.19 cm). While, variety Thanu showed the highest number of seeds per panicle (98.00) and Jaya excelled in seed yield per plant (32.77 g), per plot (2831 g), per hectare (4718 kg), and test weight (26.23 g). Seed recovery was highest in IR-64 (91.44%) and Thanu (90.36%). Across most traits, fortified varieties, including Paustic-7, Paustic-9 and Paustic-1, showed comparatively lower performance. These results indicate that conventional varieties outperform fortified ones under aerobic conditions, emphasizing the need for further improvement in biofortified paddy lines.

Keywords: Fortified rice, aerobic rice, seed quality, test weight, seed recovery, seed yield

Introduction

Rice (*Oryza sativa* L.) is the most important staple food crop among the cereals consumed by more than half of the world's population and it is one of the significant cereal commodity of the world belongs to family Graminae (Poaceae) (Lopez and Joseph, 2008) [6]. India has the largest area under rice in the world and ranks second in production (Anon., 2013) [1]. The genus *Oryza* includes 24 species of which 22 are wild and two are cultivated viz., *O. sativa* L. and *O. glaberrima*. *O. sativa* is grown in all rice growing areas, but *O. glaberrima* is confined to the only West Africa (Singh, 1988) [11].

Demand for rice in India is increasing every year and it is reached around 150 million tonnes in 2025 AD. To maintain food self-sufficiency and meet future demand, rice productivity must increase by approximately 3 per cent annually despite constraints such as declining land, labour and water resources. In this context, fortified paddy varieties have gained importance as a strategy to address widespread malnutrition by enriching rice with essential micronutrients such as iron, zinc and vitamins. These nutritionally enhanced varieties help combat deficiencies, particularly among vulnerable populations, thereby improving public health and food security. This fortification tackles prevalent micronutrient deficiencies, especially among vulnerable groups, promoting better health, reducing instances of anemia and birth defects and enhancing overall food security. By bolstering the nutritional content of a widely consumed food, fortified paddy varieties offer a practical and impactful solution to combatting malnutrition and fostering a healthier population in India. Rice is a moisture hungry crop and a prolific user of water which requires 3000-5000 liters of water to produce one kg of grain which is almost 2 to 3 times higher than any other cereal crops such as wheat and maize (Cantrell and Hettel, 2004) [3]. Rice is cultivated under four major ecosystems namely irrigated (57%), rain fed lowland (31%), rain fed upland (9%) and Deep water (3%).

Aerobic rice has been identified as a potential new technology, which can reduce water use in

rice production and produce more rice with less water. Water productivity is high and labour requirement is less under aerobic rice production system; it also minimizes greenhouse gas emission rates from rice fields. However, the hurdles in achieving potential yield under aerobic system has to be overcome by focused research, then only we can make aerobic rice a potentially viable alternative to lowland rice (Daly, 2018) [4].

Materials and Methods

A field experiment was conducted to evaluate the performance of fortified and conventional paddy (*Oryza sativa* L.) varieties under aerobic cultivation at the AICRP on Seed (Crops), University of Agricultural Sciences (UAS), GKVK, Bengaluru. The experimental site is located at 12°15' N latitude and 77°35' E longitude, at an altitude of approximately 930 m above mean sea level (MSL).

The experimental layout followed a Randomized Complete Block Design (RCBD) comprising fifteen rice varieties, with three replications for statistical robustness. The varietal treatments included both fortified and conventional genotypes: Paushtik Dhan-1 through Paushtik Dhan-9 (biofortified lines), and non-fortified cultivars including KMP-220, MAS-946-1, IR-64, Jaya, BR-2655, and Thanu. Each gross plot measured 5.0 meters by 2.0 meters, while the net plot dimensions were maintained at 4.6 meters by 1.6 meters to ensure accurate yield data collection and minimize border effects.

Varieties

V ₁ : Gangavathi sona	V ₆ : KMP-220	V ₁₁ : MTU-1010
V ₂ : IR-30864	V ₇ : MAS-26	V ₁₂ : Paustic-1 (fortified)
V ₃ : IR-64	V ₈ : MAS-946-1	V ₁₃ : Paustic-7 (fortified)
V ₄ : Jaya	V ₉ : MSN-99	V ₁₄ : Paustic-9 (fortified)
V ₅ : KMP-175	V ₁₀ : MTU-1001	V ₁₅ : Thanu

Seeds of all rice varieties were sown on raised nursery beds measuring 3.0 meters in length, 0.6 meters in width, and 0.15 meters in height, with an inter-row spacing of 20 cm. A uniform seed rate of 50 kg ha⁻¹ was adopted across treatments. The nursery beds were irrigated as needed to maintain optimal moisture conditions. At 21 days after sowing (DAS), healthy seedlings were carefully uprooted and transplanted onto the main experimental field, which had been thoroughly prepared, at a spacing of 20 cm × 10 cm.

Fertilizer application followed the recommended dose of 100:50:50 kg ha⁻¹ of N, P₂O₅, and K₂O, respectively. One-third of the nitrogen along with the entire dose of phosphorus and potassium was applied as a basal dressing prior to transplanting. The remaining two-thirds of nitrogen was administered in two equal split doses at 30 and 55 days after transplanting (DAT).

The crop was managed in accordance with the recommended package of practices to ensure optimal growth and development. Irrigation was applied based on crop requirement and all essential intercultural operations including weeding and pest control were performed as needed. Observations on growth parameters were recorded from five randomly selected plants within each plot to maintain representativeness. Similarly, yield and yield-attributing traits were measured from five randomly chosen plants and from the net plot area, with results extrapolated to express yield per hectare.

In the selected rice varieties cultivated under aerobic conditions, observations were systematically recorded on key yield-contributing parameters. These included the number of productive tillers per plant, number of seeds per panicle, seed-

setting percentage, seed yield per plant, seed yield per plot, seed yield per hectare, seed recovery percentage, test weight, and harvest index.

The experimental data were subjected to statistical analysis following Fisher's method of analysis of variance (ANOVA), as described by Gomez and Gomez (1984). The significance of treatment effects was tested at the 5% probability level ($p = 0.05$) using the F-test. Wherever significant differences were observed, critical difference (CD) values at the 5% level were computed to facilitate comparison among treatment means.

Results and Discussion

The data pertaining to different yield parameters of two seasons pooled and presented below with discussion. Among all the varieties which were observed for number of productive tillers (Table 1), the highest number of productive tillers was recorded in KMP-220 (18.67) and it was on par with variety Jaya (18.54) and lower number of productive tillers was recorded in Paustic-7 (13.54) and followed by Paustic-9 (14.78) (Fig. 1). Whereas, the highest panicle length observed among the varieties is MAS-946-1 (30.19 cm) and the lowest panicle length observed among the varieties is Paustic-7 (15.54 cm) (Table 1). Among the varieties, the highest number of seed per panicle was observed in Thanu (98.00) which was on par IR-30864 (97.00), Jaya (96.00), MSN-99 (96.00), KMP-175 (94.00), KMP-220 (93.00) and lower number of seed per panicle was observed in Paustic-7 (73.00) and followed by Paustic-9 (73.00) (Table 1) (Fig. 2). Variation in growth and yield parameters between varieties might be due to genetical background and performs of varieties under aerobic condition. Similar trends in variation for productive tillers, panicle traits, and seed yield attributes have been documented by Shah *et al.* (1999) [10], Prasad *et al.* (2001) [9], Vishwanath *et al.* (2021) [13], and Parashiva Murthy *et al.* (2011) [8], indicating the strong influence of genotype–environment interaction on rice productivity. The observed variability in growth and yield parameters among the varieties can be attributed to their genetic makeup and differential adaptability to aerobic cultivation conditions. Varietal performance under non-flooded environments is largely influenced by inherent physiological efficiency, root architecture and resource-use efficiency.

Among the varieties, highest number of chaffy seeds per panicle was recorded in paustic-9 (37.32) and highest number of filled seeds were observed in Jaya (103.33) (Table 2). Whereas, highest seed setting per cent was recorded in KMP-220 (95.22) which was followed by Jaya (94.55) and KMP-175 (91.39) and whereas the lowest seed setting (%) recorded in Paustic-7 (69.05) and Paustic-9 (75.38) (Fig. 3). The higher seed set percentage observed among certain varieties may be attributed to their genetic constitution and better adaptability to aerobic cultivation conditions. These results are in agreement with the findings of Tahir *et al.* (2003) [12], who also reported significant varietal influence on seed setting under varying environmental conditions.

The variation among all the varieties for seed yield per plant (Table 3). The highest seed yield per plant was recorded in Jaya (32.77 g) which was on par with MTU-1001 (31.91g), KMP-175 (30.13g) and the lowest seed yield per plant was observed in Paustic-7 (23.40 g) which was followed by Paustic-9 (24.68 g). The variation among all the varieties for seed yield per plot (Table 3). The highest seed yield per plot (g) was recorded in Jaya (2831g) which was on par MTU-1001 (2743g), KMP-175 (2731g) and KMP-220 (2686g) and the lowest seed yield per plot in Paustic-9 (2152g) followed by Paustic-7 (2185g). For

seed yields per hectare the highest seed yield per hectare was recorded in Jaya (4718 kg ha⁻¹) followed by MTU-1001 (4572 kg ha⁻¹), KMP-175 (4551 kg ha⁻¹) and the lowest of seed yield was recorded in Paustic-9 (3587 kg ha⁻¹) which was followed by the Paustic-7 (3642 kg ha⁻¹) and Paustic-1 (3734 kg ha⁻¹). Variation in growth and yield parameters between varieties might be due to genetical background and performs of varieties under aerobic condition. The same variability was reported by Zahid *et al.* (2005) [14] and Mirza *et al.* (1992) [7] in Paddy.

Results on seed recovery per cent, 1000 seed weight and harvest index were presented in Table 4. Seed recovery is one of the most important distinguishing features used by several scientists to differentiate several crop varieties. The variation on seed recovery observed among all varieties. The highest seed recovery which was recorded in IR-64 (91.44%) and which on par with Thanu (90.36%) and Jaya (90.35%) whereas, the lowest seed recovery was recorded in MTU-1010 (84.91%) followed by MAS-26 (85.98%), KMP-175 (86.35%) and Paustic-7 (87.44%) (Fig. 4). Thousand seeds weight is one of the most important distinguishing features used by several scientists to differentiate several crop varieties. The study revealed that thousand seeds weight differed significantly among the varieties (Table 4). Significantly higher thousand seeds weight was observed in Jaya

(26.23g) and it was on par with MTU-1001 (25.36 g), MAS-26 (24.21 g), MAS-946-1 (23.76g), IR-30864 (23.58g) and IR-64 (21.23g). Whereas, lower thousand seeds weight was observed in Gangavathisona (16.04 g), followed by MSN-99 (18.65g). Similar pattern of classification was reported earlier by Parashiva Murthy *et al.*, (2011) [8]. Harvest index is one of the most important distinguishing features used by several scientists to differentiate several crop varieties (Table 4). The highest harvest index in Jaya, MSN-99 and Thanu (0.65) and it was on par with IR-30864 (0.64). Whereas the lowest was recorded in IR-64 (0.49) followed by MTU-1010 (0.50). Similar findings on seed recovery, thousand seed weight and harvesting index were reported by Bharali *et al.* (1994) [2] and Tahir *et al.* (2003) [12] in paddy. Most the growth and yield parameters were less in fortified varieties of Paddy compared to other paddy varieties. Correlations coefficient was analyzed for various parameters (Table 5). Days to Maturity shows a significant negative correlation with chaffy seeds per panicle, indicating that longer maturity times might relate to fewer chaffy seeds. Parameters like number of tillers at harvest, number of productive tillers, panicle weight, straw yield and seed yield exhibit strong positive correlations among themselves

Table 1: Variation in number of productive tillers, panicle length and number of seed per panicle of different varieties of paddy cultivated under aerobic condition

Varieties	Number of productive tillers	Panicle length (cm)	Number of seed per panicle
V ₁ : Gangavathi sona	17.54	23.77	93
V ₂ : IR-30864	16.11	19.53	97
V ₃ : IR-64	16.23	22.41	80
V ₄ : Jaya	18.54	22.92	96
V ₅ : KMP-175	17.92	18.84	94
V ₆ : KMP-220	18.67	26.43	93
V ₇ : MAS-26	16.27	26.30	83
V ₈ : MAS-946-1	16.51	30.19	87
V ₉ : MSN-99	16.86	28.00	96
V ₁₀ : MTU-1001	17.67	21.24	81
V ₁₁ : MTU-1010	16.67	29.62	78
V ₁₂ : Paustic-1	15.28	24.93	76
V ₁₃ : Paustic-7	13.54	15.54	73
V ₁₄ : Paustic-9	14.78	20.02	77
V ₁₅ : Thanu	16.08	20.17	98
S. Em±	0.65	2.12	7.34
CD (P=0.05)	1.92	6.11	21.89
CV%	12.8	8.1	6.9

Table 2: Variation in number of chaffy seeds per panicle, number of filled seed per panicle and seed setting percentage of different varieties of paddy cultivated under aerobic condition

Varieties	Number of chaffy seeds per panicle	Number of filled seed per panicle	Seed setting (%)
V ₁ : Gangavathi sona	29.33	87.67	89.45
V ₂ : IR-30864	29.33	87.00	84.16
V ₃ : IR-64	26.67	93.67	84.77
V ₄ : Jaya	16.00	103.33	94.55
V ₅ : KMP-175	22.33	93.83	91.39
V ₆ : KMP-220	32.50	84.50	95.22
V ₇ : MAS-26	29.19	88.83	82.98
V ₈ : MAS-946-1	26.24	97.83	84.20
V ₉ : MSN-99	32.43	85.83	86.89
V ₁₀ : MTU-1001	13.11	101.33	86.72
V ₁₁ : MTU-1010	28.52	90.00	82.62
V ₁₂ : Paustic-1	34.50	81.50	77.93
V ₁₃ : Paustic-7	34.83	72.00	69.05
V ₁₄ : Paustic-9	37.32	81.17	75.38
V ₁₅ : Thanu	26.63	90.67	84.01
S. Em±	2.22	5.73	2.93
CD (P=0.05)	6.42	16.55	8.45
CV%	5.8	7.2	9.3

Table 3: Variation in seed yield per plant, seed yield per plot and seed yield per hectare of different paddy varieties cultivated under aerobic condition

Varieties	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield (kg ha ⁻¹)
V ₁ :Gangavathi sona	29.81	2504	4173
V ₂ : IR-30864	31.09	2325	3875
V ₃ : IR-64	27.04	2269	3781
V ₄ : Jaya	32.77	2831	4718
V ₅ : KMP-175	30.13	2731	4551
V ₆ : KMP-220	29.81	2686	4476
V ₇ : MAS-26	26.60	2350	3917
V ₈ : MAS-946-1	27.88	2395	3992
V ₉ : MSN-99	30.77	2314	3857
V ₁₀ : MTU-1001	31.91	2743	4572
V ₁₁ : MTU-1010	25.91	2292	3786
V ₁₂ : Paustic-1	24.36	2240	3734
V ₁₃ : Paustic-7	23.40	2185	3642
V ₁₄ : Paustic-9	24.68	2152	3587
V ₁₅ : Thanu	31.41	2474	4123
S. Em±	2.14	43.26	21.23
CD (P=0.05)	6.52	129.47	60.16
CV%	11.2	9.5	12.7

Table 4: Variation in seed recovery, test weight and harvest index of different varieties of paddy cultivated under aerobic condition

Varieties	Seed recovery (%)	Test weight (g)	Harvest Index
V ₁ :Gangavathi sona	89.23	16.04	0.57
V ₂ : IR-30864	87.46	23.58	0.64
V ₃ : IR-64	91.44	21.23	0.49
V ₄ : Jaya	90.35	26.23	0.65
V ₅ : KMP-175	86.35	21.28	0.56
V ₆ : KMP-220	90.26	20.21	0.53
V ₇ : MAS-26	85.98	24.21	0.55
V ₈ : MAS-946-1	88.73	23.76	0.56
V ₉ : MSN-99	89.74	18.65	0.64
V ₁₀ : MTU-1001	87.90	25.36	0.56
V ₁₁ : MTU-1010	84.91	22.71	0.50
V ₁₂ : Paustic-1	88.34	21.39	0.53
V ₁₃ : Paustic-7	87.44	22.19	0.58
V ₁₄ : Paustic-9	88.11	20.65	0.56
V ₁₅ : Thanu	90.36	19.87	0.64
S. Em±	1.34	0.64	0.9
CD (P=0.05)	2.89	1.80	0.25
CV%	7.7	8.1	6.8

Table 5: Correlation between growth and yield parameters of paddy varieties under aerobic condition

	Plant height	Days to maturity	Number of tillers at harvest	Panicle length	Number of productive tillers	Number of spikelets per panicle	Number of chaffy seeds per panicle	Panicle weight	Straw yield	Seed yield
Plant height	1.00									
Days to maturity	0.42	1.00								
Number of tillers at harvest	0.40	0.63	1.00							
Panicle length	0.41	-0.03	0.16	1.00						
Number of productive tillers	0.38	0.55	0.98	0.19	1.00					
No. of spikelets per panicle	0.11	0.54	0.88	0.07	0.85	1.00				
No. of chaffy seeds per panicle	0.25	-0.65	-0.93	0.05	-0.90	-0.91	1.00			
Panicle weight	0.38	0.55	0.95	0.16	0.97	0.87	-0.94	1.00		
Straw yield	0.29	0.53	0.94	0.17	0.95	0.93	-0.93	0.96	1.00	
Seed yield	0.40	0.57	0.95	0.31	0.96	0.91	-0.89	0.95	0.98	1.00

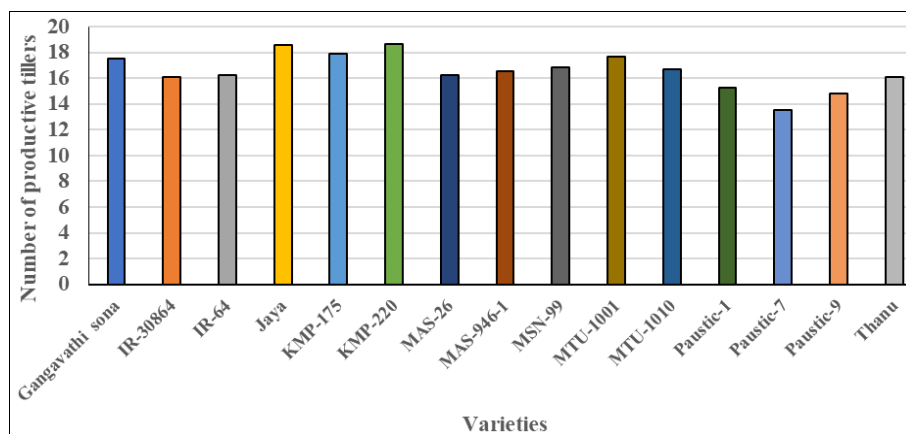


Fig 1: Variation in number of productive tillers of different varieties of paddy cultivated under aerobic condition

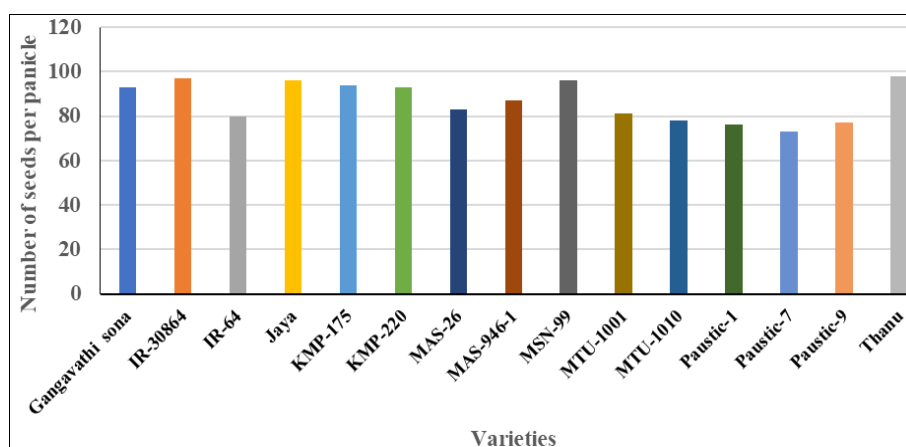


Fig 2: Variation in number of seeds per panicle of different varieties of paddy cultivated under aerobic condition

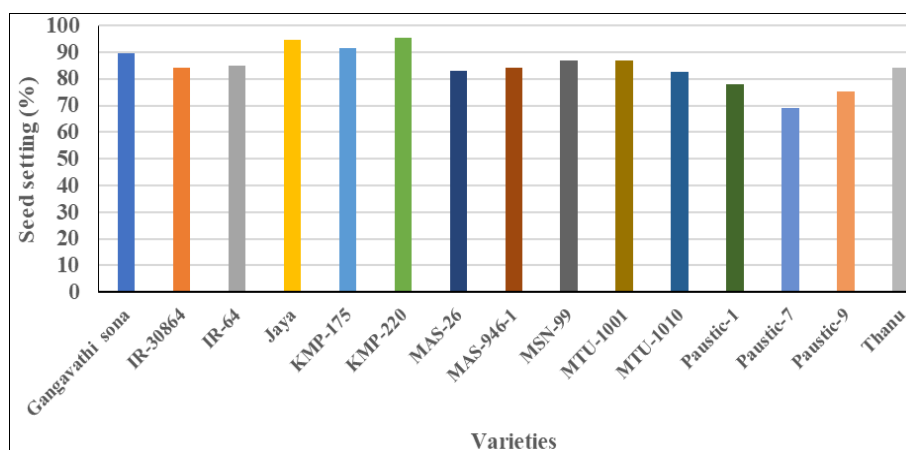


Fig 3: Variation in seed setting percentage of different varieties of paddy cultivated under aerobic condition

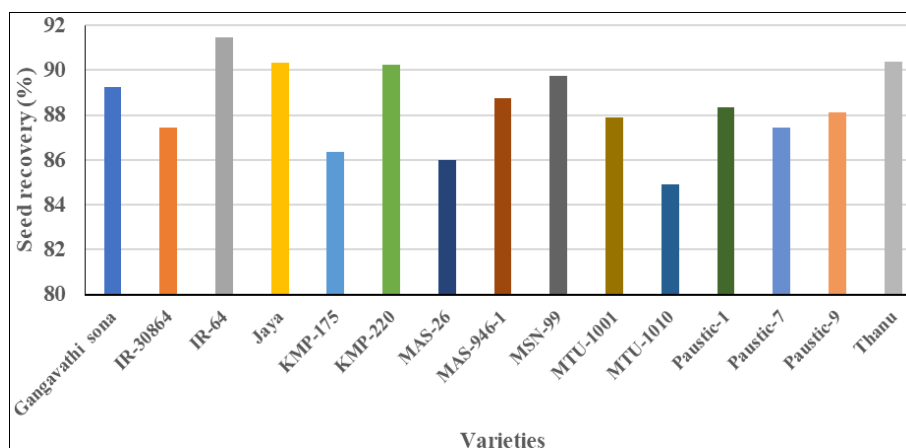


Fig 4: Variation in seed recovery percentage of different varieties of paddy cultivated under aerobic condition

Conclusion

The comparative evaluation of fortified and traditional paddy varieties under aerobic conditions revealed significant differences in yield attributes and seed quality traits. Conventional varieties such as Jaya, Thanu and KMP-220 consistently outperformed fortified lines across key parameters, including seed yield, test weight and seed setting percentage. Although fortified varieties hold nutritional advantages, their agronomic performance remains suboptimal under water-limited conditions. These findings underscore the necessity for further breeding and agronomic optimization to enhance the adaptability and yield potential of biofortified rice varieties in aerobic cultivation systems.

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