Indian Journal of Agricultural Sciences **95** (1): 010–015, January 2025/Article
https://doi.org/10.56093/ijas.v95i1.133868

Performance of semi-dry rice (*Oryza sativa*) varieties under different plant spacing

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Received: 28 February 2023; Accepted: 06 November 2024

ABSTRACT

Semi-dry rice (*Oryza sativa* L.) is a new attractive alternative to the conventional puddled transplanted rice production technology for lowering labour and irrigation water requirements in the command areas of India. A study was carried out during the rainy (*kharif*) seasons of 2019 and 2020 at College of Agriculture (University of Agricultural Sciences, Bengaluru, Karnataka), V C Farm, Mandya, Karnataka, to assess the growth and yield of semi dry rice varieties under different plant spacing. The experiment was conducted in a split-plot design (SPD) comprised of various combinations of two plant spacing (20 cm and 30 cm row spacing) allocated to the main plots and eight varieties (V_1, KMP-175; V_2, RNR-15048; V_3, RNR-15038; V_4, Rasi; V_5, MTU-1001; V_6, MTU-1010; V_7, IR-64 and V_8, Gangavathisona) in sub plots, replicated thrice. The result revealed that 20 cm row spacing recorded higher plant height (82.7 cm), dry matter production (90.00 g/hill), leaf area index (4.57), panicle/m (292), grain yield (4605 kg/ha) and straw yield (6389 kg/ha) compared to 30 cm spacing. Among the different varieties KMP-175 produced higher plant height (90.3 cm), dry matter production (121.16 g/hill), leaf area index (5.04), panicle length (22.47 cm), grain yield (5086 kg/ha) and straw yield (7139 kg/ha) compared to other varieties. The overall analysis revealed that KMP-175 under closer crop spacing (20 cm row spacing) was the best management practices for enhancing yield of semi dry rice.

Keywords: Dry matter production, Semi dry rice, Spacing, Yield

Rice (*Oryza sativa* L.) is the second most vital staple crop globally after wheat. Asia, home to more than a third of the world's population, produces 90% of the world's total rice, with Southeast Asia playing a particularly significant role. India's rice production, encompassing 43.6 million hectares, yields 118.8 million tonnes. Annually with an average productivity of 2812 kg/ha, making it the second-largest producer globally after China (Anonymous 2023). Semi dry rice is initially sown on dry seed beds like an upland crop, benefiting from monsoon rains. By the 4th or 5th leaf stage, as rainfall intensifies or sufficient water is released from tanks or irrigation projects, the fields are transitioned into wetland rice (Raj *et al.* 2014). The spacing of rice plants plays a crucial role in determining growth and yield by influencing factors such as solar radiation interception, crop canopy development, and the accumulation of dry matter, all of which contribute to efficient resource utilization.

Close spacing is practiced by certain farmers, whereas wide spacing is adopted by others. Mutual shadowing favours more straw yield over grain yield. Wider plant spacing (30 cm) on the other hand reduces grain production per unit area by utilizing more solar radiation and nutrients, while optimal plant spacing guarantees that the plant grows properly with its aerial and subsurface portions (Sultana *et al.* 2012). Likewise, the tillering pattern and the number of spikelets/panicle are affected by plant spacing, which significantly impacts rice yield per unit area. Therefore, optimizing plant spacing should involve careful consideration of various crop management techniques (Mahato *et al.* 2017). Choosing rice cultivars or varieties with high yield potential and quality across varying nutrient levels and plant populations is crucial in current rice research. Rice cultivars that demonstrate superior water and nutrient use efficiency, as well as enhanced resistance to biotic and abiotic stresses, should be prioritized for achieving higher yields in semi-dry rice conditions. In view of these, the present investigation was formulated to study performance of semi dry varieties under different plant spacing.

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MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2019 and 2020 at College of Agriculture (University of Agricultural Sciences, Bengaluru, Karnataka), V C Farm, Mandya, Karnataka. The soil at the experimental site was sandy loam, alkaline with a *p*H of 9.02, and had low electrical conductivity (0.37 dS/m). Soil fertility analysis revealed low levels of organic carbon (0.39%), available nitrogen (182.12 kg N/ha), and available potassium (122.32 kg K_2O/ha), while available phosphorus was relatively high (78.74 kg P_2O_5/ha). The experiment was conducted in a split-plot design (SPD) with three replications, where main plots were assigned 2-row spacings (20 cm and 30 cm). Each main plot was sub-divided into 8 sub-plots to accommodate 8 different rice varieties (V_1, KMP-175; V_2, RNR-15048; V_3, RNR-15038; V_4, Rasi; V_5, MTU-1001; V_6, MTU-1010; V_7, IR-64; and V_8, Gangavathisona). The treatments were randomly assigned to both the main plots and sub-plots, and the seeds were sown in rows. Lines are made at a distance of 20 cm and 30 cm as per treatment and seeds are sown in the lines and covered manually. The varieties taken for experiment were medium duration with 120–140 days duration. Biometric measurements of growth parameters were recorded at four distinct stages of crop development (30, 60, 90 days after sowing and during harvest) for 5 randomly selected plants from each net plot area, which were labelled accordingly. Light interception was assessed by determining the light transmission ratio (LTR) across three levels of the crop canopy: top, middle, and bottom, using a lux meter. Actual measurements during the reproductive growth phase were conducted using a Metravi 1332 light meter.

Statistical analysis: The analysis of variance (ANOVA) was carried out using Fisher's method, following the guidelines set forth by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant growth parameters

Plant height (cm): In different spacings, higher plant height (82.7 cm) was noticed in 20 cm row spacing compared to 30 cm row spacing (77.6 cm) on pooled basis. Among different varieties, KMP- 175 recorded taller plants (90.32 cm) followed by MTU-1010 (86.23 cm) and were significantly superior to rest of the varieties. RNR-15048 recorded lower plant height (71.64 cm). Closer spacing, viz. 20 cm row spacing achieved higher plant height compared to the 30 cm row spacing (Table 1). This could possibly be attributed to more intense inter and intra plant for space, sunlight and other inputs in contrast to wider spacing of 30 cm, which create a competition and increases the plant height for availing the resources. Similar findings were noticed by Jena *et al.* (2010) and Gautam *et al.* (2018) in aerobic rice. Among the different varieties, KMP-175 exhibited greater plant height in comparison to the other varieties. Another potential factor could be genetic diversity among individual varieties, influencing traits like growth rate and height variations within the species and better utilization of available resources which may result in absorption of nutrients from the soil coupled with an increase in cell division which increases in plant shape and size in aerobic rice (Basavaraja *et al.* 2010, Kumar *et al.* 2015) and dry seeded irrigated rice (Gautam *et al.* 2018).

Number of tillers/m²: The row spacing of 20 cm resulted in a significantly higher number of tillers/m^2 (339.2) compared to 30 cm row spacing (298.4). Among the various varieties, MTU-1001 exhibited the highest number of tillers/m^2 (363.4). However, it was on par with Rasi (350.2) and statistically superior as compared to rest of varieties. RNR-15038 recorded lower tillers/m^2 (274.8) compared to other varieties. The higher tiller density per square meter observed with 20 cm row spacing can be attributed to the increased plant population and enhanced nutrient uptake compared to the 30 cm row spacing. The optimal plant density in the narrower row spacing facilitated efficient utilization of nutrients and moisture, along with improved solar energy harvesting due to reduced weed competition, potentially contributing to the higher tiller production per square meter compared to wider spacing (30 cm). These findings align with those reported by Joshi *et al.* (2016) for direct-seeded rice and Gautam *et al*. (2018) for dry-seeded irrigated rice. Whereas, in different varieties higher number of tillers was produced by MTU-1001. Such variances in tillers between cultivars could be due to variations in their genetic ancestry which resulted changes in their genetic background for such characteristics.

Leaf area index (LAI): Significantly higher LAI (4.57) was noticed in 20 cm row spacing compared to (4.12) 30 cm row spacing. Among the different varieties, KMP-175 produced significantly higher LAI (5.04) as compared to rest of the varieties, but was on par with MTU-1010 (4.87). Gangavathisona (3.76) produced lower LAI compared to all other varieties. Closer spacing (20 cm) produced higher LAI compared to wider spacing (Table 1). It was mainly due to production of more tillers as resulted in more number of leaves in a unit area without much variation of leaf breadth when compared to wider spacing levels (30 cm). The present findings are in close association with Ghuman *et al.* (2008). KMP-175 showed a greater leaf area index than the other varieties.

Genetic makeup of variety associated with good ideotypic structure might also be the key factor for higher leaf area index. Similar finding was recorded by Gautam *et al.* (2008), Kumar *et al.* (2015).

Dry matter production (g/hill): Dry matter production was significantly higher (90.00 g/hill) in the 20 cm row spacing compared to the 30 cm row spacing (75.42 g/hill). Whereas in varieties, KMP-175 produced significantly higher dry matter production (121.16 g/hill) compared to other varieties and Gangavathisona (65.61 g/hill) produced the lower dry matter production. Higher initial plant population in closer plant (20 cm) spacing, which produce more plants and tillers per unit area, this leads to effective utilization of available resources in both above and below

Table 1 Effect of plant spacing and varieties on growth parameters of semi dry rice

Treatment	Plant height (cm)			No. tillers/m^2			LAI			Dry matter production (g/hill)			Light transmission ratio (%)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Row spacing (M)															
M_1, 20 cm	81.4	84.0	82.7	323.5	354.8	339.2	4.55	4.60	4.57	86.64	93.36	90.00	46.43	47.50	46.96
M_2, 30 cm	76.3	78.8	77.6	287.0	309.8	298.4	4.06	4.18	4.12	73.93	76.90	75.42	50.72	51.14	50.93
SEm±	0.80	0.84	0.81	4.595	5.61	4.92	0.07	0.07	0.06	1.34	1.69	1.24	0.57	0.59	0.57
CD (*P*=0.05)	4.85	5.11	4.90	27.96	34.11	29.93	0.41	0.40	0.39	8.17	11.08	7.55	3.50	3.61	3.48
Varieties (V)															
V_1, KMP-175	89.4	91.2	90.3	329.2	354.0	341.6	5.20	4.88	5.04	117.92	124.40	121.16	55.83	56.25	56.04
V_2, RNR-15048	70.0	73.3	71.6	267.3	296.7	282.0	3.75	3.98	3.86	65.17	69.26	67.22	43.85	44.22	44.04
V_3, RNR-15038	73.0	76.6	74.8	257.5	292.0	274.8	3.85	4.10	3.98	67.90	72.27	70.09	44.45	45.23	44.84
V_4, Rasi	84.7	84.3	84.5	337.8	362.5	350.2	4.64	4.62	4.63	85.46	90.80	88.13	50.69	51.52	51.11
V_5, MTU-1001	77.4	81.5	79.4	351.2	375.7	363.4	4.16	4.37	4.27	74.81	80.27	77.54	47.99	49.10	48.54
V_6, MTU-1010	85.9	86.6	86.2	326.2	344.8	335.5	4.95	4.79	4.87	89.35	93.57	91.46	54.32	54.68	54.50
V_7, IR-64	79.8	82.9	81.3	302.0	329.7	315.8	4.28	4.47	4.37	78.02	82.89	80.46	48.83	50.18	49.50
V_8, Gangavathisona	70.6	74.7	72.6	270.8	302.8	286.8	3.62	3.91	3.76	63.64	67.59	65.61	42.63	43.39	43.01
SEm±	1.63	1.73	1.63	7.552	7.36	7.28	0.10	0.08	0.08	2.37	2.56	2.08	1.08	1.16	1.06
CD (*P*=0.05)	4.71	5.02	4.73	21.88	21.33	21.10	0.29	0.23	0.23	6.88	7.45	6.03	3.13	3.36	3.06
Interaction (M × V)															
SEm±	2.25	2.38	2.28	12.99	15.86	13.91	0.19	0.17	0.18	3.80	4.79	3.51	1.63	1.68	1.62
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

LAI, Leaf area index.

ground compared to wider spacing (30 cm) (Joshi *et al.* 2016, Gautam *et al.* 2018). KMP-175 produced higher dry matter production compared to other varieties. It was mainly due to availability of more vegetative growth periods and more plant height associated with higher LAI compared to other varieties.

Light transmission ratio (%): Light transmission ratio was recorded at 60 DAS. Significantly higher light transmission ratio (50.93%) was observed in 30 cm row spacing in comparison to 20 cm row spacing (46.96%). Among the different varieties significantly higher light transmission ratio (56.04%) was noticed in KMP-175. However, it was comparable to MTU-1010 (54.50%) and outperformed other varieties. Higher light transmission ratio was recorded in wider spacing (30 cm) is due to lower plant population in unit area. In closer spacing (20 cm) light interception reduced due to higher population which reduces light penetration in to the lower leaves. Similar finding was noticed by Ghuman *et al.* (2008) in wet seeded rice.

Yield parameters and yield

Panicle/m^2: In different spacings, significantly higher panicle/m^2 was observed in closer row spacing (292) compared to 30 cm row spacing (255). Among the different varieties, MTU-1010 produced higher number of panicle/m^2 (311). However, it was found on par with MTU-1001 (307), Rasi (302.25) and KMP-175 (293.42) and statistically superior than other varieties. A 15% increase in panicles/m^2 was observed in the 20 cm row spacing compared to the 30 cm spacing. This difference could be attributed to higher tiller production per unit area and improved early tiller development leading into the crop's reproductive phase. These results are in accordance with the observations of Koireng *et al.* (2019) in direct seeded rice. Among the varieties, KMP-175 produced lengthier panicle. Improved growth and development are correlated with efficient uptake of nutrients from soil by the more vigorous and extensive root systems and efficient use of available resources and rapid movement of photosynthetic products from leaf to panicle compared to other varieties. Similar finding was noticed by Kumar *et al.* (2015).

Panicle length (cm): 30 cm row length resulted in significantly higher panicle length (20.19 cm) in comparison to 20 cm row spacing (18.95 cm). While in varieties, KMP-175 exhibited a greater panicle length (22.47 cm), and it was comparable with MTU-1010 (21.61 cm) and higher over rest of the varieties (Table 2). Higher panicle length was noticed in 30 cm row spacing compared to 20 cm row spacing. Panicle length was significantly influenced by the plant population. Wider spaced (30 cm) plants produced less panicle/m^2; receiving more nutrients, moisture and light which ultimately lead to produce the longest length of the panicle. Among the varieties, KMP-175 produced lengthier panicle. It was mainly because of higher uptake of nutrients and water from the soil compared to other varieties. Enhanced growth and development are correlated with efficient uptake of nutrients from soil by the more vigorous and extensive root systems and effective utilization of available resources in faster rate compared to other varieties (Gautam 2008).

Panicle weight (g): Panicle weight was found non-significant between spacing. Among the various varieties, KMP-175, KMP-175 recorded a significantly higher panicle weight (3.25 g) followed by RNR-15048 (3.15 g) and RNR-15038 (3.03 g). Gangavathisona recorded lower panicle weight (2.06 g). KMP-175 recorded more panicle weight compared to other varieties. This was primarily due to increased dry matter production and leaf area index (LAI), leading to enhanced photosynthesis and accumulation of photosynthates, resulting in superior grain filling compared to other varieties. These results are consistent with Ningaraju *et al.* (2015).

Number of filled grains/panicle: Significantly more number of filled grains/panicle (97.02) was produced in 30 cm row spacing compared to 20 cm row spacing (87.18). Among the various rice varieties, a significantly greater number of filled grains/panicle (133.10) were observed in RNR-15048 subsequently RNR-15038 (126.92) and KMP-175(115.57). Lower filled grains/panicle were noticed in MTU-1001 (62.73). Higher filled grains were recorded in 30 cm row spacing compared to 20 cm row spacing (Table 2). Anthesis and grain development are influenced by environmental factors like nutrient availability, moisture levels, and light which could potentially have been more conducive in wider spacing (30 cm). This might have helped in better availability of resources at reproductive stage resulting in increased translocation of photosynthates during panicle development causing more appropriation and an increased number of filled spikelets. RNR-15048 produced higher filled grains panicle. It was mostly attributed due to genetic makeup of cultivar and enhanced carbon and nitrogen assimilate transfer from source to sink. The same kinds of results were also reported by Basavaraja *et al.* (2010) and Sridhara *et al.* (2011) in aerobic rice.

Test weight (g): Test weight was non-significant between spacing. Among the different varieties, significantly higher test weight (24.47 g) was observed in MTU- 1010 followed by MTU-1001 (24.20 g) and Gangavathisona (23.88 g). RNR-15048 recorded the lower test weight (16.21 g) compared to other varieties. Test weight (1000-grain weight) recorded was statistically identical between 20 and 30 cm spacing levels since test weight is a varietal characteristic that is seldom affected by spacing levels (Alam *et al.* 2012, Rasool *et al.* 2013). Among the varieties, MTU-1010 given more test weight in comparison to other varieties because of bold grain nature. Grain weight varied directly with size of the seed, which is the genetic character of different rice genotypes (Gautam *et al.* 2008, Mallareddy and Padmaja 2013, Kiran *et al.* 2015).

Yield (*kg/ha*): Significantly higher grain yield and straw production were observed in the 20 cm row spacing (4605 kg/ha and 6389 kg/ha) compared to the 30 cm row spacing (4115 kg/ha and 5727 kg/ha), which was 12% higher than

Table 2 Effect of plant spacing and varieties on yield parameters of semi dry rice

Treatment	Number of panicle/m^2			Panicle length (cm)			Panicle weight (g)			Number of filled grains/panicle			Test weight (g)		
	2019	2019	2019	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Row spacing (M)															
M_1, 20 cm	276	309	292	18.69	19.20	18.95	2.46	2.63	2.55	84.97	89.38	87.18	21.50	21.53	21.52
M_2, 30 cm	246	263	255	20.00	20.37	20.19	2.67	2.89	2.78	93.43	100.60	97.02	21.70	21.87	21.79
SEm±	4.43	5.07	4.24	0.21	0.18	0.19	0.04	0.07	0.06	1.327	1.58	1.39	0.06	0.06	0.06
CD (*P*= 0.05)	26.97	30.85	25.79	1.28	1.07	1.15	NS	NS	NS	8.08	9.59	8.44	NS	NS	NS
Varieties (V)															
V_1, KMP-175	281	306	293	22.41	22.52	22.47	3.19	3.30	3.25	111.10	120.03	115.57	21.3	21.45	21.37
V_2, RNR-15048	223	250	236	18.13	18.30	18.22	3.10	3.20	3.15	129.80	136.40	133.10	16.09	16.33	16.21
V_3, RNR-15038	215	241	228	18.82	18.62	18.72	2.95	3.11	3.03	122.90	130.93	126.92	16.51	16.56	16.54
V_4, Rasi	292	313	302	20.89	21.03	20.96	2.24	2.41	2.32	74.73	80.67	77.70	23.58	23.78	23.68
V_5, MTU-1001	293	321	307	16.04	18.02	17.03	2.41	2.28	2.35	62.40	63.05	62.73	24.12	24.28	24.20
V_6, MTU-1010	295	328	311	21.56	21.65	21.61	2.53	2.65	2.59	79.90	86.43	83.17	24.37	24.57	24.47
V_7, IR-64	255	281	268	19.76	19.73	19.75	2.06	2.15	2.11	70.30	74.53	72.42	22.79	22.96	22.87
V_8, Gangavathisona	233	256	244	17.15	18.42	17.79	2.04	2.08	2.06	62.45	67.87	65.16	24.08	23.68	23.88
SEm±	6.36	6.87	6.27	0.38	0.32	0.33	0.07	0.07	0.06	2.05	2.22	2.13	0.12	0.22	0.16
CD (*P*=0.05)	18.42	19.90	18.17	1.09	0.93	0.97	0.20	0.19	0.18	5.94	6.44	6.16	0.33	0.64	0.46
Interaction (M × V)															
SEm±	12.53	14.42	11.99	0.59	0.50	0.53	0.12	0.19	0.15	3.75	4.45	3.92	0.17	0.17	0.15
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3 Effect of plant spacing and varieties on yield of semi dry rice

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)			Harvest index (%)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Row spacing (M)									
M_1, 20 cm	4540	4670	4605	6260	6518	6389	42.02	41.75	41.88
M_2, 30 cm	4011	4219	4115	5625	5829	5727	41.63	41.99	41.81
SEm±	78	69	53	93	96	79	0.07	0.15	0.09
CD (*P*=0.05)	473	418	321	568	586	478	NS	NS	NS
Varieties (V)									
V_1, KMP-175	4969	5202	5086	6965	7312	7139	41.61	41.56	41.58
V_2, RNR-15048	3804	3898	3851	5266	5499	5383	41.94	41.45	41.69
V_3, RNR-15038	3879	4053	3966	5335	5597	5466	42.11	42.06	42.08
V_4, Rasi	4615	4798	4706	6383	6604	6493	41.94	42.09	42.01
V_5, MTU-1001	4166	4349	4257	5838	6007	5922	41.58	42.03	41.81
V_6, MTU-1010	4780	4976	4878	6562	6835	6699	42.12	42.14	42.13
V_7, IR-64	4306	4496	4400	5961	6188	6074	41.94	42.13	42.04
V_8, Gangavathisona	3686	3786	3736	5232	5348	5290	41.35	41.49	41.42
F-test	**	**	**	**	**	**	NS	NS	NS
SEm±	92	97	85	132	133	111	0.56	0.75	0.46
CD (*P*=0.05)	267	280	246	384	385	320	NS	NS	NS
Interaction (M × V)									
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	220	194	149	264	272	222	0.19	0.40	0.28
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

wider spacing (30 cm). Whereas in rice varieties, higher grain yield and straw was recorded in KMP-175 (5086 kg/ha and 7139 kg/ha) and it was significantly superior over other varieties except for grain yield, which was comparable to MTU 1010. Greater yield was observed in the narrower spacing of 20 cm compared to the wider spacing of 30 cm (Table 3). This could potentially be explained by higher plant population compared to wider spacing. Adequate availability of nutrients, light and space when planted with wider spacing (30 cm) resulted in improvement in yield attributing characters and ultimately increased the grain yield per plant but there was significant reduction in seed yield/ha at 30 cm row spacing due to less population Murthy *et al.* (2011). Among the various varieties, KMP-175 generated a greater grain yield compared to other varieties. This might be due to significant increase in panicle/m^2, the grain count per panicle and the weight of 1000-grain. Similar results were also reported by Murthy *et al.* (2011) and Kiran *et al.* (2015).

Harvest index (%): Non-significant difference was noticed in harvest index for plant spacing and varieties. However among spacings, 20 cm row spacing recorded higher harvest index (41.88%) compared to 30 cm spacing (41.81%). Among the varieties MTU-1010 recorded higher harvest index (42.13%) over other varieties.

Based on the two-year study, it can be concluded that cultivating the variety KMP-175 with 20 cm row spacing using the semi-dry method of rice cultivation proves advantageous in terms of growth parameters and yield.

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