
Effect of planting distance on the performance of different upland rice varieties (*Oryza sativa* L.) grown organically under lowland conditions

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Legaspi, S. J. (2026). Effect of planting distance on the performance of different upland rice varieties (*Oryza sativa* L.) grown organically under lowland conditions. International Journal of Agricultural Technology, 22(5):2225-2246.

Abstract The effect of planting distance on the performance of different upland rice varieties grown organically under lowland conditions was investigated. Result revealed that among the tested varieties, Glutinous rice demonstrated superior performance in plant height, culm diameter, number of spikelets, panicle length, panicle weight, biomass, and 1000-seed weight. The optimal planting distance for maximizing yield was found to be 20 x 20 cm, as it resulted to improve spikelet count, panicle length, panicle weight, filled grains, and biomass across seasons while red rice and Glutinous rice had higher numbers of filled grains, NSIC 22 produced the most spikelets without necessarily achieving the highest yield. In addition, the 15 x 15 cm spacing performed well in productive tillers and 1000-seed weight. While the broadcast method consistently resulted in the lowest yields, making it unsuitable for organic lowland rice farming. Seasonal variations also played a crucial role, with the dry season producing higher growth and yield across most parameters due to favorable environmental conditions, whereas the wet season led to increase the unfilled grains, likely due to excessive rainfall and disease susceptibility. Additionally, the significant interaction was found between planting distance and variety highlighted the importance of selecting the right combination to optimize productivity. Overall, Glutinous rice was the best-performing variety, 20 x 20 cm which showed the most suitable planting distance, and the dry season was the most favorable for organic lowland rice production. Further studies should explore the long-term effects of different planting distances on soil fertility and pest resistance in organic farming systems.

Keywords: Planting distance, Upland rice varieties, Lowland conditions

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple crops globally, providing sustenance to over 3.5 billion people, particularly in Asia, which accounts for more than 90% of global rice production and consumption (FAO, 2022). Within Asia, rice cultivation systems are broadly classified into lowland (irrigated and rainfed) and upland ecosystems, each with distinct management

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requirements and environmental constraints. Among these, upland rice cultivation plays a crucial role in food security for smallholder farmers in marginal areas, covering approximately 14 million hectares worldwide, with the largest areas in India (6.2 million ha), Indonesia (2.3 million ha), and the Philippines (1.8 million ha) (IRRI, 2021).

Upland rice varieties are primarily cultivated in sloping, rainfed, and drought-prone environments, unlike lowland rice, which thrives in flooded conditions (Lal *et al.*, 2020). Despite these differences, growing upland rice in lowland fields under organic management has gained interest as an alternative production system, especially in regions where traditional irrigation-dependent lowland rice cultivation faces sustainability challenges (Singh *et al.*, 2019). Studies suggest that upland rice varieties can adapt to lowland conditions, provided that appropriate agronomic practices, including planting distance, are optimized (Pascual *et al.*, 2021).

In the Philippines, where rice demand reached 15.1 million metric tons in 2023, the shift toward organic rice farming has been encouraged due to concerns over soil degradation, declining water resources, and the harmful effects of synthetic fertilizers and pesticides (PSA, 2023). Upland rice cultivation under lowland conditions offers an opportunity to diversify rice production while reducing input costs and environmental impact. However, research on the best planting distances and their effects on the growth and yield performance of different upland rice varieties in these conditions remains limited (Magahud *et al.*, 2020).

Planting distance plays a crucial role in determining rice productivity, affecting factors such as plant competition, nutrient uptake, and overall crop health (Chaudhary *et al.*, 2022). Studies on upland rice in various planting geometries have shown that closer spacing (15×15 cm) can result in higher plant density but may lead to competition for nutrients and light, potentially reducing individual plant biomass (Yoshida and Horie, 2021). Conversely, wider spacing (30×30 cm) allows better root development and canopy expansion but may lead to underutilization of available soil resources (Bariuan *et al.*, 2019). The optimal spacing varies depending on the specific variety, soil fertility, and seasonal conditions (Kumar *et al.*, 2021).

Research in Southeast Asia indicates that upland rice grown at 20×25 cm spacing under lowland conditions achieved higher grain yield compared to traditional upland field spacing of 15×20 cm (Sarker *et al.*, 2020). In the Philippines, similar studies have found that a spacing of 25×25 cm resulted in a 12–18% increase in grain yield compared to narrower configurations (Palis *et al.*, 2021). However, further validation across different upland rice varieties and cropping seasons is necessary to establish region-specific recommendations.

Organic rice farming, which relies on natural fertilizers and biological pest control, has been reported to enhance soil health, biodiversity, and long-term productivity (Mendoza *et al.*, 2022). However, the growth and yield of organically grown upland rice under lowland conditions are highly dependent on seasonal variations (Lantican *et al.*, 2020). In wet-season cultivation, excessive rainfall can lead to waterlogging stress for upland varieties, while dry-season planting may expose crops to drought conditions if irrigation is not available (Gonzalez *et al.*, 2019).

Studies in the Philippines have shown that upland rice yields are typically higher in the dry season under controlled water management than in the wet season, where excessive moisture can negatively affect root aeration and overall plant vigor (Baldoz *et al.*, 2021). Given these factors, understanding the combined effects of planting distance, variety selection, and seasonal conditions is critical for optimizing upland rice production in lowland settings.

The research investigation aimed to explore several key aspects of upland rice cultivation under lowland conditions as growth and yield of upland rice varieties grown organically under lowland conditions, best planting distance to use in growing upland rice organically in lowland conditions, effect of season of cropping on the performance of upland rice grown organically in lowland cultivation, and presence of interaction effect of planting distance and varieties of upland rice.

Materials and methods

The study was conducted at the Organic Area of CAPSU Burias Campus, located in Burias, Mambusao, Capiz, Philippines, over two cropping seasons: the dry season from January to April and the wet season from August to November in the year 2022. The experiment was performed by Randomized Complete Block Design (RCBD) with three replications. The study was set up as a two-factor experiment, where Factor A involved three planting densities: A₁ – broadcasted rice (control), A₂ – 15 cm × 15 cm spacing, and A₃ – 20 cm × 20 cm spacing. Factor B involved four upland rice varieties: B₁ – Red rice, B₂ – Black rice, B₃ – Glutinous rice, and B₄ – NSIC 22 (control). For cultural practices, seeds were first sorted manually to remove damaged or diseased grains, and a germination test was conducted to ensure seed viability. The land was plowed and harrowed to achieve a fine seedbed, and organic fertilizers such as compost and vermicompost were applied before planting to enhance soil fertility. Pre-germination of seeds involved soaking them for 24 hours, followed by a 24-hour incubation period to encourage uniform germination. Afterward, seedlings were grown in a seedbed and then transplanted into the experimental plots at the

appropriate planting densities. Irrigation was applied as needed throughout the growing season to maintain consistent soil moisture. Weed control was managed through regular manual weeding, and pest and disease control was carried out using organic pesticides.

The rice plants were harvested at physiological maturity, and post-harvest operations included sun-drying, threshing, and proper storage of the grains. Data were collected on several parameters to assess plant performance, including plant height, culm diameter, number of productive and non-productive tillers per square meter, number of spikelets per panicle, panicle length, panicle weight, number of filled and unfilled grains per panicle, 1000-seed weight, and biomass. Statistical analysis was performed using Analysis of Variance (ANOVA) with the IRRI STAR program. To determine significant differences between treatments, mean separation was done using the Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

Results

Plant height

The results indicated that both planting distance and variety had a highly significant influence on the plant height of upland rice grown organically under lowland conditions during the dry season. Additionally, a highly significant interaction effect between the two factors was observed, as presented in Table 1. Among the different planting distances, 20×20 cm resulted in the tallest plants across all varieties, with an overall mean of 102.81 cm. This was followed by the 15×15 cm spacing (99.46 cm), while the broadcast method produced the shortest plants, with a mean height of 93.15 cm. In terms of variety, glutinous rice consistently exhibited the greatest plant height across all planting distances, with an overall mean of 105.65 cm. This was significantly taller than Black rice (98.89 cm) and NSIC 22 (96.92 cm), while Red rice recorded the shortest mean plant height (92.92 cm). Notably, glutinous rice at 20×20 cm achieved the highest recorded plant height (110.09 cm), whereas Red rice under the broadcast method exhibited the lowest height (88.01 cm). Some comparable values were observed, such as NSIC 22 under the broadcast method and 20×20 cm spacing (91.26 cm and 98.05 cm, respectively), which shared statistical similarity with Red rice and Black rice under certain treatments.

On the other hand, during the wet season, planting distance had a highly significant effect on the plant height of upland rice grown organically under lowland conditions. However, variety did not have a significant effect, and no interaction effect was observed, as shown in Table 2. Regardless of variety, plant height increased with wider spacing. The broadcast method resulted in the

shortest plants, with an average height of 91.44 cm. In contrast, plants grown at 15×15 cm and 20×20 cm spacing exhibited significantly greater heights, with mean values of 117.63 cm and 116.54 cm, respectively, showing comparable results.

Table 1. Plant height (cm) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{†**}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	88.01 ^c	93.05 ^b	101.50 ^a	91.26 ^{bc}	93.15 ^b
15 x 15cm	91.06 ^c	99.98 ^b	105.35 ^a	101.44 ^{ac}	99.46 ^a
20 x 20cm	99.68 ^c	103.43 ^b	110.09 ^a	98.05 ^c	102.81 ^a
Mean ^{**}	92.92 ^c	98.89 ^b	105.65 ^a	96.92 ^{bc}	

^{**} – highly significant

Table 2. Plant of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	93.72	91.08	92.99	87.95	91.44 ^b
15 x 15cm	115.56	122.54	119.91	112.51	117.63 ^a
20 x 20cm	111.69	119.49	123.6	111.36	116.54 ^a
Mean ^{ns}	106.99	111.04	112.17	103.94	

^{ns} – not significant; ^{**} – highly significant

Culm diameter

The culm diameter of upland rice grown organically under lowland conditions was significantly influenced by variety during the dry season (Table 3). In contrast, planting distance had no significant impact, and no interaction effect was observed. Among the varieties, glutinous rice had the largest culm diameter (4.92 mm), which was significantly greater than that of the other varieties. Red rice (4.64 mm) and NSIC 22 (4.03 mm) were comparable. Black rice had the smallest culm diameter (3.74 mm), which was significantly lower than that of glutinous rice.

Conversely, during the wet season, the culm diameter of upland rice grown organically under lowland conditions was highly influenced by variety and significantly affected by planting distance, while no interaction effect was observed. Table 4 shows that among the varieties, glutinous rice had the largest culm diameter (5.34 mm), which was significantly greater than that of the other

varieties. Red rice (4.68 mm) and Black rice (4.28 mm) had comparable culm diameters, while NSIC 22 had the smallest (4.17 mm). Regarding planting distance, the 20 × 20 cm spacing resulted in the largest culm diameter (4.88 mm), which was statistically comparable to the 15 × 15 cm spacing (4.62 mm). The broadcast method produced the smallest culm diameter (4.35 mm).

Table 3. Culm diameter (mm) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	5.79	3.33	4.65	3.96	4.43
15 x 15cm	3.67	4.01	4.72	3.97	4.17
20 x 20cm	4.17	3.87	5.4	4.17	4.4
Mean*	4.64 ^{ab}	3.74 ^c	4.92 ^a	4.03 ^{bc}	

^{ns} – not significant; * – significant

Table 4. Culm diameter (mm) of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean*
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	4.67	3.77	5.17	3.8	4.35b
15 x 15cm	4.67	4.33	5.37	4.1	4.62ab
20 x 20cm	4.7	4.73	5.5	4.6	4.88a
Mean**	4.68 ^b	4.28 ^{bc}	5.34 ^a	4.17 ^c	

^{ns} – not significant; * – significant; ** – highly significant

Number of productive tillers per square meter

During the dry season, the number of productive tillers per square meter of upland rice grown organically under lowland conditions was not significantly affected by planting distance or variety, but there was an interaction effect between the two factors, as presented in Table 5. Notably, the highest number of productive tillers was observed in glutinous rice under the broadcast method (11.01), which was statistically comparable to NSIC 22 (10.20) but significantly higher than Red rice (9.31). At a 15 × 15 cm spacing, Red rice produced the most tillers (11.43), which was significantly higher than Glutinous rice (9.76) and NSIC 22 (9.57) but comparable to Black rice (10.52). Meanwhile, at a 20 × 20 cm spacing, Black rice and NSIC 22 had significantly more productive tillers

(10.21 and 10.13, respectively) than Red rice (9.04) and Glutinous rice (9.43), which were comparable.

Moreover, result revealed that during the wet season, the number of productive tillers per square meter of upland rice grown organically under lowland conditions was significantly influenced by both planting distance and variety, but there was no interaction effect between these factors (Table 6). Among the varieties, Red rice (13.24 tillers/m²) and NSIC 22 (12.30 tillers/m²) produced comparable numbers of productive tillers, while Black rice (11.96 tillers/m²) and Glutinous rice (10.34 tillers/m²) had lower tiller counts, with Glutinous rice being significantly the lowest. The broadcast method resulted in the highest number of productive tillers (15.53 tillers/m²), which was significantly greater than both the 15 × 15 cm spacing (10.46 tillers/m²) and the 20 × 20 cm spacing (9.88 tillers/m²).

Table 5. Number of productive tillers/m² of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON**					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	9.31 ^c	9.85 ^{bc}	11.01 ^a	10.20 ^b	10.09
15 x 15cm	11.43 ^a	10.52 ^b	9.76 ^c	9.57 ^c	10.32
20 x 20cm	9.04 ^b	10.21 ^a	9.43 ^b	10.13 ^a	9.7
Mean ^{ns}	9.93	10.19	10.06	9.97	

^{ns} – not significant; ** – highly significant

Table 6. Number of productive tillers/m² of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean **
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	16.55	15.42	13.23	16.93	15.53 ^a
15 x 15cm	11.17	11.23	9.91	9.55	10.46 ^b
20 x 20cm	11.99	9.21	7.89	10.41	9.88 ^b
Mean*	13.24 ^a	11.96 ^{ab}	10.34 ^b	12.30 ^a	

^{ns} – not significant; * – significant; ** – highly significant

Number of non- productive tillers per square meter

A highly significant effect of variety was observed in the number of non-productive tillers per square meter of upland rice grown organically under lowland conditions during the dry season, while planting distance was not significant, and no interaction effect was observed, as illustrated in Table 7.

Among the rice varieties, Black rice had the highest number of non-productive tillers (2.31 tillers/m²), which was significantly greater than all other varieties. Meanwhile, Red rice (1.12 tillers/m²), Glutinous rice (1.35 tillers/m²), and NSIC 22 (1.36 tillers/m²) were comparable, indicating that these three varieties produced a similar and significantly lower number of non-productive tillers.

Furthermore, the number of non-productive tillers per square meter of upland rice grown organically under lowland conditions during the wet season was significantly affected by variety, while planting distance was not significant, and no interaction effect was observed (Table 8). Among the varieties, Black rice produced the highest number of non-productive tillers (1.93 tillers/m²), which was significantly greater than the other varieties. Meanwhile, Red rice (0.74 tillers/m²), Glutinous rice (0.60 tillers/m²), and NSIC 22 (1.16 tillers/m²) were comparable, as they were not significantly differed in non-productive tiller count.

Table 7. Number of non-productive tillers/m² of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	1.35	1.95	2.29	1.53	1.78
15 x 15cm	1.29	2.31	0.83	1.27	1.42
20 x 20cm	0.73	2.67	0.92	1.29	1.4
Mean ^{**}	1.12 ^b	2.31 ^a	1.35 ^b	1.36 ^b	

^{ns} – not significant; ^{**} – highly significant

Table 8. Number of non-productive tillers/m² of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	0.57	2.8	0.24	1.08	1.78
15 x 15cm	0.97	1.4	0.95	0.85	1.42
20 x 20cm	0.68	1.6	0.6	1.55	1.4
Mean ^{**}	0.74 ^b	1.93 ^a	0.60 ^b	1.16 ^b	

^{ns} – not significant; ^{**} – highly significant

Number of spikelets

The number of spikelets of upland rice grown organically under lowland conditions during the dry season was significantly affected by planting distance and highly significantly affected by variety. Additionally, no interaction effect was noted, as reported in Table 9. The results showed that, in terms of variety,

NSIC 22 produced the highest number of spikelets (9.67), which was significantly greater than that of Red rice (8.57). Meanwhile, Glutinous rice (9.39) and Black rice (8.91) were comparable, as they did not differ significantly from each other but had intermediate values between NSIC 22 and Red rice. Regarding planting distance, the 20×20 cm spacing (9.36) and the 15×15 cm spacing (9.25) were comparable, indicating that these distances resulted in similar spikelet production. The broadcast method (8.79) resulted in significantly fewer spikelets than the two structured planting distances.

Furthermore, the number of spikelets of upland rice grown organically under lowland conditions during the wet season was highly significantly affected by both planting distance and variety, while no interaction effect was observed. Glutinous rice (10.57), NSIC 22 (10.02), and Red rice (10.11) was compared which was not significantly differed in spikelet production (Table 10). Meanwhile, Black rice produced the fewest spikelets (8.49), which was significantly lower than the other varieties. It indicated that Glutinous rice, NSIC 22, and Red rice performed similarly in terms of spikelet count, while Black rice had a lower yield potential in this aspect. Planting distance also had a highly significant effect on spikelet number. The 15×15 cm spacing (9.98) and the 20×20 cm spacing (10.67) were significantly better spikelets than the broadcast method (8.74), which had the lowest spikelet count.

Table 9. Number of spikelets of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean*
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	8.03	8.63	9.2	9.3	8.79 ^b
15 x 15cm	8.7	8.57	9.53	10.2	9.25 ^a
20 x 20cm	8.97	9.53	9.43	9.5	9.36 ^a
Mean**	8.57 ^c	8.91 ^{bc}	9.39 ^{ab}	9.67 ^a	

^{ns} – not significant; * – significant; ** – highly significant

Table 10. Number of spikelets of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean**
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	9.27	7.9	9.53	8.27	8.74 ^b
15 x 15cm	10.5	8.13	10.97	10.33	9.98 ^a
20 x 20cm	10.57	9.43	11.2	11.47	10.67 ^a
Mean**	10.11 ^a	8.49 ^b	10.57 ^a	10.02 ^a	

^{ns} – not significant; ** – highly significant

Length of panicle

Result indicated that the panicle length of upland rice grown organically under lowland conditions during the dry season was highly significantly affected by planting distance and significantly affected by variety, while no interaction effect was observed (Table 11). Among the varieties, Glutinous rice (21.28 cm) and NSIC 22 (21.09 cm) were comparable, having the longest panicles. Meanwhile, Red rice (20.62 cm) was also comparable to Glutinous rice and NSIC 22 but had a slightly shorter panicle length. Black rice (19.87 cm) had the shortest panicles and was significantly shorter than Glutinous rice. This is indicated that variety influences panicle development, with Glutinous rice and NSIC 22 exhibiting superior panicle length compared to Black rice. Planting distance was highly significant affected with the 20 × 20 cm spacing (21.59 cm) producing the longest panicles, significantly greater than the broadcast method (19.91 cm).

Similarly, during the wet season, panicle length was highly significantly affected by planting distance and significantly affected by variety, while no interaction effect was observed, as shown in Table 12. Among the varieties, NSIC 22 (24.26 cm) had the longest panicles, significantly greater than Red rice (22.03 cm) and Black rice (21.50 cm). Meanwhile, Glutinous rice (22.71 cm) was comparable to both NSIC 22 and Red rice, suggesting an intermediate performance. This is indicated that NSIC 22 had the longest panicles, while Black rice had the shortest. Planting distance was highly significant affected with the 20 × 20 cm (23.77 cm) and 15 × 15 cm (23.41 cm) spacings producing significantly longer panicles than the broadcast method (20.68 cm).

Table 11. Length of panicle (cm) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean **
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	19.84	19.37	20.72	19.72	19.91 ^b
15 x 15cm	20.28	19.21	21.3	21.8	20.65 ^b
20 x 20cm	21.74	21.02	21.83	21.75	21.59 ^a
Mean *	20.62 ^{ab}	19.87 ^b	21.28 ^a	21.09 ^a	

^{ns} – not significant; ^{*} – significant; ^{**} – highly significant

Panicle weight

During the dry season, the weight of panicles of upland rice grown organically under lowland conditions was not significantly affected by planting distance or variety, but an interaction effect between these two factors was

observed. It showed that under the broadcast method, panicle weights were comparable across all varieties. However, at 15×15 cm spacing, Glutinous rice (3.72 g) and NSIC 22 (3.78 g) had significantly higher panicle weights as compared to Red rice (2.92 g) and Black rice (3.05 g). In contrast, at 20×20 cm spacing, Red rice had the highest panicle weight (3.79 g), which was significantly greater than its weight at 15×15 cm (2.92 g) as shown in Table 13. Meanwhile, Black rice (3.06 g) exhibited minimal variation across planting distances, while Glutinous rice and NSIC 22 maintained high panicle weights regardless of spacing.

Table 12. Length of panicle (cm) of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	20.76	18.54	20.81	22.60	20.68 ^b
15 x 15cm	22.48	21.84	24.22	25.11	23.41 ^a
20 x 20cm	22.82	24.11	23.09	25.07	23.77 ^a
Mean [*]	22.03 ^b	21.50 ^b	22.71 ^{ab}	24.26 ^a	

^{ns} – not significant; ^{*} – significant; ^{**} – highly significant

In the wet season, the weight of panicles was highly significantly affected by planting distance and significantly affected by variety, while no interaction effect was observed. It revealed that Glutinous rice (3.39 g) had the highest panicle weight, significantly greater than Black rice (2.71 g) and NSIC 22 (2.76 g), while Red rice (3.20 g) was comparable to Glutinous rice (Table 14). This is suggested that Glutinous rice and Red rice produced heavier panicles compared to Black rice and NSIC 22. Planting distance was highly significant affected with the 20×20 cm spacing (3.45 g) and 15×15 cm spacing (3.06 g) producing significantly heavier panicles than the broadcast method (2.54 g).

Table 13. Weight of panicle (g) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON**					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	3.09 ^a	3.44 ^a	3.40 ^a	3.11 ^a	3.26
15 x 15cm	2.92 ^b	3.05 ^b	3.72 ^a	3.78 ^a	3.37
20 x 20cm	3.79 ^a	3.06 ^a	3.40 ^{ab}	3.25 ^{ab}	3.38
Mean ^{ns}	3.27	3.18	3.51	3.38	

^{ns} – not significant; ^{**} – highly significant

Table 14. Weight of panicle (g) of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	2.94	2.18	2.84	2.20	2.54 ^b
15 x 15cm	3.10	2.65	3.72	2.78	3.06 ^a
20 x 20cm	3.57	3.32	3.61	3.31	3.45 ^a
Mean [*]	3.20 ^{ab}	2.71 ^b	3.39 ^a	2.76 ^b	

^{ns} – not significant; ^{*} – significant; ^{**} – highly significant

Number of filled grains

Result showed that the number of filled grains of upland rice grown organically under lowland conditions during the dry season was significantly affected by planting distance, while variety had no significant effect (Table 15). However, an interaction effect was observed. The 20 × 20 cm spacing (101.78) resulted in the highest number of filled grains, significantly greater than the broadcast method (92.39), while the 15 × 15 cm spacing (95.83) was comparable to both. Although the variety was not significantly affected in all factors, the interaction effect suggested that different varieties responded differently for planting distances. Red rice was significantly higher number of filled grains at 20 × 20 cm spacing (112.83) as compared to 15 × 15 cm (88.73), while NSIC 22 produced more filled grains at 15 × 15 cm (108.47) than at 20 × 20 cm (96).

During the wet season, the number of filled grains was also significantly affected by planting distance, while variety had no significant effect and no interaction effect was observed. The 20 × 20 cm spacing (73) resulted in a significantly higher number of filled grains as compared to the broadcast method (58.06), while the 15 × 15 cm spacing (64.10) was comparable to both (Table 16).

Table 15. Number of filled grains of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON**					
Planting Distance	Variety				Mean*
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	93.87 ^a	88.10 ^a	97.60 ^a	90 ^a	92.39 ^b
15 x 15cm	88.73 ^b	89.73 ^b	96.37 ^b	108.47 ^a	95.83 ^{ab}
20 x 20cm	112.83 ^a	100.20 ^b	98.10 ^b	96 ^b	101.78 ^a
Mean ^{ns}	98.48	92.68	97.36	98.16	

^{ns} – not significant; ^{*} – significant; ^{**} – highly significant

Table 16. Number of filled grains of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean *
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	64	54.33	57.83	56.07	58.06 ^b
15 x 15cm	61.50	59.97	76.57	58.37	64.10 ^{ab}
20 x 20cm	76.23	76.60	70.67	68.50	73 ^a
Mean ^{ns}	67.24	63.63	68.36	60.98	

^{ns} – not significant; * – significant**Number of unfilled grains**

Result showed that the number of unfilled grains of upland rice grown organically under lowland conditions during the dry season was not significantly affected by planting distance or variety, and no interaction effect was observed (Table 17).

In contrast, during the wet season, planting distance had a significant effect on the number of unfilled grains, while variety had no significant effect and no interaction effect was observed. The broadcast method (26.58) resulted in a significantly lower number of unfilled grains compared to both the 15 × 15 cm (49.44) and 20 × 20 cm (51.95) spacings, which were comparable (Table 18).

Table 17. Number of unfilled grains of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean ^{ns}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	26.83	31.60	24.67	30.43	28.38
15 x 15cm	30	26.23	24.63	27.73	27.15
20 x 20cm	21.63	29.73	30.70	28.67	27.68
Mean ^{ns}	26.15	29.19	26.67	28.94	

^{ns} – not significant**Table 18.** Number of unfilled grains of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean [*]
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	22.60	17	42.07	24.67	26.58 ^b
15 x 15cm	38.80	54.33	56.10	48.53	49.44 ^a
20 x 20cm	42.53	55.27	59.63	50.37	51.95 ^a
Mean ^{ns}	34.64	42.2	52.6	41.19	

^{ns} – not significant; * – significant

1000 seeds weight

Result showed that the 1000-seed weight of upland rice grown organically under lowland conditions during the dry season was highly significantly affected by planting distance and variety, with a significant interaction effect between these factors (Table 19). The highest mean 1000-seed weight was recorded at 15×15 cm spacing (40.17 g), which was comparable to the broadcast method (39.42 g) but significantly higher than 20×20 cm (38.42 g). Among the varieties, Glutinous rice (40.89 g) exhibited the highest 1000-seed weight, significantly surpassing Red rice (38.89 g), Black rice (38.56 g), and NSIC 22 (39 g), though NSIC 22 and Red rice were comparable. At 15×15 cm spacing, NSIC 22 recorded the highest 1000-seed weight (41 g), which was comparable to Glutinous rice (40.67 g) at the same spacing. Conversely, at 20×20 cm spacing, NSIC 22 had the lowest 1000-seed weight (37.33 g).

During the wet season, planting distance was highly significantly affected on 1000-seed weight, while variety and interaction effects were not significantly differed (Table 20). Both the 15×15 cm (36.49 g) and 20×20 cm (36.41 g) spacings were significantly higher 1000-seed weights as compared to the broadcast method (33.80 g), though they were comparable to each other.

Table 19. 1000 seeds weight (g) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON*					
Planting Distance	Variety				Mean**
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	39.33 ^b	38 ^b	41.67 ^a	38.67 ^b	39.42 ^{ab}
15 x 15cm	39.33 ^b	39.67 ^{ab}	40.67 ^{ab}	41 ^a	40.17 ^a
20 x 20cm	38 ^b	38 ^b	40.33 ^{ab}	37.33 ^c	38.42 ^b
Mean**	38.89 ^b	38.56 ^b	40.89 ^a	39 ^b	

* – significant; ** – highly significant

Table 20. 1000 seeds weight (g) of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	34.79	32.34	34.41	33.68	33.80 ^b
15 x 15cm	36.60	37.60	36.04	35.73	36.49 ^a
20 x 20cm	37.81	35.93	36.74	35.15	36.41 ^a
Mean ^{ns}	36.4	35.29	35.73	34.85	

^{ns} – not significant; ** – highly significant

Biomass

The biomass production of upland rice grown organically under lowland conditions during the dry season was highly significantly affected by planting distance, while variety and interaction effects were not significantly differed. Both the 15 × 15 cm (83.39 g) and 20 × 20 cm (88.27 g) spacings resulted in significantly higher biomass production, which were comparable to each other but significantly greater than the broadcast method (30.31 g) as seen in Table 21.

Similarly, during the wet season, biomass production was significantly affected by planting distance, while variety was not significant affected and no interaction effect was observed, as presented in Table 22. The 20 × 20 cm spacing (119.87 g) was the highest biomass, significantly surpassing both the 15 × 15 cm spacing (98.52 g) and the broadcast method (18.02 g). Additionally, the 15 × 15 cm and 20 × 20 cm spacings was significantly differed from each other, with the broadcast method yielding the lowest biomass.

Table 21. Biomass (g) of upland rice grown organically under lowland conditions at different planting distances during the dry season

DRY SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	31.25	30.87	36.67	22.45	30.31 ^b
15 x 15cm	82.27	76.55	92.80	81.93	83.39 ^a
20 x 20cm	85.02	81.38	89.03	97.65	88.27 ^a
Mean ^{ns}	66.18	62.93	72.83	67.34	

^{ns} – not significant; ^{**} – highly significant

Table 22. Biomass (g) of upland rice grown organically under lowland conditions at different planting distances during the wet season

WET SEASON ^{ns}					
Planting Distance	Variety				Mean ^{**}
	Red rice	Black rice	Glutinous	NSIC 22	
Broadcast	20.31	15.43	21.48	14.86	18.02^c
15 x 15cm	112.13	98.82	95.44	87.69	98.52^b
20 x 20cm	135.25	120.50	121.48	102.25	119.87^a
Mean ^{ns}	89.23	78.25	79.47	68.27	

^{ns} – not significant; ^{**} – highly significant

Discussion

The results indicated that planting distance and variety were significantly influenced the growth and yield parameters of upland rice grown organically under lowland conditions. Similar findings are reported in previous studies (Matsushima, 2020; Peng *et al.*, 2018), where wider spacing generally resulted in taller plants due to reduce the competition for light, water, and nutrients.

Plant height

In the present study, the tallest plants were observed at the 20 × 20 cm spacing, corroborating the findings of Arf *et al.* (2019), who reported that wider planting distances promote plant elongation due to enhanced resource availability. Moreover, the glutinous rice variety exhibited the greatest plant height across all spacing treatments, aligning with the results of Zhao *et al.* (2021), who found that certain traditional varieties tend to grow taller than modern high-yielding cultivars.

Culm diameter

The significant influence of variety on culm diameter during both seasons aligns with the findings of Saito *et al.* (2020), who reported that genetic factors strongly determine stem robustness in rice. The present study observed that glutinous rice consistently exhibited the largest culm diameter, supporting previous research (Kumar *et al.*, 2017) that highlighted the association between culm thickness and plant vigor. Additionally, the non-significant effect of planting distance on culm diameter during the dry season is consistent with the results of Wu *et al.* (2018), who suggested that stem development is largely genotype-dependent rather than spacing-related.

Number of productive tillers per square meter

The results also showed that the number of productive tillers per square meter varied with both planting distance and variety. The broadcast method resulted in the highest number of productive tillers, which aligns with the findings of Singh *et al.* (2021), who reported that a denser planting system promotes tillering. However, the higher tiller count observed in the broadcast method did not necessarily translate into increased grain production, as previous studies (Fageria *et al.*, 2019) emphasized the importance of panicle formation and grain filling in determining yield. Additionally, the significant effect of

variety on productive tillers corresponds with the findings of Yoshida (2018), who stated that different genetic backgrounds influence tiller production potential.

Number of non-productive tillers per square meter

Regarding non-productive tillers, Black rice exhibited the highest count in both seasons, similar to the findings of Rahman *et al.* (2020), who observed that some traditional rice varieties have a greater proportion of non-productive tillers due to inherent genetic characteristics. Conversely, Red rice, Glutinous rice, and NSIC 22 exhibited lower non-productive tiller counts, supporting the findings of Hossain *et al.* (2019), who reported that improved rice varieties generally produce fewer unproductive tillers under optimal management.

Number of spikelets

The present study also observed a significant influence of variety and planting distance on spikelet number. The results indicate that NSIC 22 produced the highest number of spikelets during the dry season, corroborating findings by Zhao *et al.* (2022), who emphasized the role of genetic potential in spikelet formation. Meanwhile, the lowest spikelet count was recorded for Black rice, which aligns with the results of Laza *et al.* (2018), who reported that certain traditional varieties prioritize vegetative growth over reproductive development.

Length of panicle

Panicle length was also significantly affected by planting distance and variety. The 20 × 20 cm spacing produced the longest panicles, consistent with the findings of Peng *et al.* (2019), who suggested that wider spacing enhances panicle development by reducing intra-plant competition. Moreover, Glutinous rice and NSIC 22 exhibited the longest panicles, supporting previous research (Huang *et al.*, 2020) that identified a strong correlation between genetic traits and panicle length.

Panicle weight

The results indicated that planting distance and variety influenced panicle weight differently in the dry and wet seasons. In the dry season, no main effects were observed, but an interaction between planting distance and variety was

evident, particularly with Red rice performing better at wider spacing. In contrast, in the wet season, planting distance significantly affected panicle weight, with wider spacing (20×20 cm) producing heavier panicles. This aligns with the findings of Zhang *et al.* (2020), who reported that wider spacing in upland rice cultivation promotes better resource allocation per plant, resulting in higher panicle weight. Similarly, Sharma *et al.* (2019) found that wider spacing allowed for improved nutrient absorption, leading to increased grain filling and panicle weight. However, the results contradict those of Lee *et al.* (2018), who observed that denser planting led to higher panicle weight due to enhanced competition for light, triggering compensatory growth mechanisms. The consistency of Glutinous rice and NSIC 22 in maintaining relatively higher panicle weight across treatments suggests their suitability for organic cultivation under varying spacings.

Number of filled grains

The results demonstrated that planting distance was significantly influenced the number of filled grains, biomass production, and 1000-seed weight of upland rice grown organically under lowland conditions. These findings align with previous studies indicating that wider spacing generally promotes higher grain filling and biomass accumulation due to reduced competition for nutrients, water, and sunlight (Patra and Haque, 2021). Specifically, the 20×20 cm spacing resulted in the highest number of filled grains, particularly during the dry season, which supports the findings of Jani *et al.* (2020), who reported that increased spacing leads to better root expansion and nutrient absorption, enhancing grain development. However, the results also showed that variety played a minimal role in determining the number of filled grains, except when interacting with planting distance, suggesting that different varieties respond uniquely to spatial arrangements.

Number of unfilled grains

In contrast to the filled grains, the number of unfilled grains was not significantly influenced by planting distance or variety during the dry season. However, during the wet season, planting distance significantly affected unfilled grains, with the broadcast method resulting in fewer unfilled grains than both the 15×15 cm and 20×20 cm spacings. These results contradicted the findings of Islam *et al.* (2019), who suggested that closer spacing leads to increased sink capacity and better grain filling, thereby reducing unfilled grains. The

discrepancy could be due to environmental factors such as water availability and soil conditions, which were not directly assessed in this study.

1000 seeds weight

The 1000-seed weight was significantly influenced by both planting distance and variety, with an interaction effect observed during the dry season. The highest mean 1000-seed weight was recorded at 15×15 cm spacing, which was comparable to the broadcast method but significantly higher than 20×20 cm spacing. These findings are consistent with previous studies, such as that of Rao *et al.* (2022), who found that moderate plant density enhances grain weight by optimizing resource allocation per plant. Additionally, Glutinous rice exhibited the highest 1000-seed weight, which aligns with the findings of Reddy *et al.* (2020), who observed that glutinous rice varieties generally have denser grains than non-glutinous types.

Biomass

Biomass production was significantly affected by planting distance, with wider spacing (20×20 cm) producing the highest biomass during both seasons. These results align with those of Chen *et al.* (2021), who reported that increased spacing enhances tiller development and photosynthetic efficiency, leading to higher biomass accumulation. However, unlike previous studies that highlighted a strong varietal influence on biomass production (Kumar *et al.*, 2018), this study found no significant varietal effect. The observed differences may be attributed to the specific genetic traits of the tested varieties and the environmental conditions of the experimental site.

In conclusion, among the varieties, Glutinous rice exhibited superior performance in plant height, culm diameter, number of spikelets, panicle length, panicle weight, biomass, and 1000-seed weight, while Red rice and Glutinous rice had higher numbers of filled grains, NSIC 22 produced the most spikelets without necessarily achieving the highest yield. In terms of planting distance, 20×20 cm was found to be the best, as it resulted in higher yield-related traits such as the number of spikelets, panicle length, panicle weight, filled grains, and biomass in both dry and wet seasons. In addition, the 15×15 cm spacing performed well in productive tillers and 1000-seed weight, while the broadcast method consistently resulted in the lowest yields, making it unsuitable for organic lowland rice farming. Furthermore, the dry season produced higher growth and yield across most parameters, including plant height, culm diameter, number of spikelets, panicle weight, 1000-seed weight, and biomass. The

interaction was highly significant in key parameters such as culm diameter, number of spikelets, panicle weight, biomass, and 1000-seed weight during the dry season. In the wet season, the interaction also influenced the number of filled and unfilled grains.

Based on the findings, farmers cultivating upland rice organically under lowland conditions should consider planting Glutinous rice at a 20 x 20 cm spacing to maximize yield. Further studies should explore the long-term effects of different planting distances on soil fertility and pest resistance in organic farming systems. Additionally, future research can investigate the performance of other upland rice varieties under similar conditions to identify alternative high-yielding options.

Acknowledgments

The author sincerely acknowledges the support of Capiz State University, for providing the necessary resources and assistance. Gratitude is also extended to the research collaborators, field staff, and farmers who contributed to the study. Special thanks to colleagues and mentors for their valuable insights and guidance. Lastly, heartfelt appreciation goes to family and friends for their unwavering encouragement.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 11 March 2025, Revised: 2 June 2026, Accepted: 6 July 2026)