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Growth Responses and Yield of *Oryza sativa* L. on Earthen Pond–Based Floating Bed

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ABSTRACT

This study evaluated the growth response and yield performance of *Oryza sativa* L. grown under an earthen pond–based floating bed system compared with the traditional soil-based planting method. Specifically, the study examined the chemical properties of soil and water, vegetative growth parameters and yield. Soil was alkaline, while water was neutral to slightly alkaline with adequate nutrient levels The experiment followed a quantitative descriptive design with replicated trials. Growth parameters measured included shoot length, leaf length, number of leaves, leaf area index (LAI) and root length, while yield parameters included number of productive tillers, panicle length, 1000-grain weight, grain filling percentage, and grain yield mass. Independent samples t-tests were used to determine significant differences between the two systems. Results showed that the floating bed system significantly improved shoot length (60, 90 DAT), leaf length (60 DAT), and number of leaves (90 DAT), while the traditional method resulted in higher leaf area index, longer roots, and longer panicles at 90 DAT. However, most yield parameters—including productive tillers, 1000-grain weight, grain filling percentage, and grain yield mass—did not differ significantly @ 0.05. Both systems achieved high grain filling percentages and comparable grain yield. Overall, the floating bed system demonstrated comparable yield performance and can serve as a viable alternative rice cultivation method, particularly in flood-prone or waterlogged areas.

Keywords: rice cultivation; floating bed system; grain yield; vegetative growth; alternative farming

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple crop and a primary source of food security in many Asian countries (FAO, 2023). However, conventional soil-based rice cultivation is increasingly challenged by flooding, waterlogging, and land limitations, particularly in climate-vulnerable regions (IRRI, 2022). These environmental constraints necessitate the exploration of alternative cultivation systems that can sustain rice production under unfavorable conditions.

The earthen pond–based floating bed system has emerged as a potential alternative farming approach, especially in flood-prone and water-saturated areas. Floating agriculture has been traditionally practiced in parts of South and Southeast Asia and has recently gained research attention as a climate adaptation strategy (FAO 2018). Unlike traditional planting, this system utilizes floating substrates that allow crops to grow above the water surface. Previous studies report that floating systems can maintain adequate nutrient supply and water availability, although variations in root development and canopy expansion may occur (Hossain et al., 2020; Widodo et al., 2025).

Although floating agriculture has been widely practiced in countries such as Bangladesh and Indonesia, most existing studies have focused on vegetable crops and floating cultivation structures. Limited empirical evidence is available regarding the growth and yield performance of rice cultivated in earthen pond–based floating bed systems, particularly under Philippine conditions. Furthermore, comparative studies evaluating both vegetative growth responses and yield components between floating and conventional rice cultivation remain scarce. This knowledge gap limits the scientific basis for promoting floating bed systems as a climate-resilient rice production strategy.

This study posits that although vegetative growth characteristics may differ between systems, grain yield performance under floating bed culture can be comparable to traditional cultivation. These findings contribute to sustainable agriculture strategies, particularly for flood-affected and climate-vulnerable regions.

Conceptual Framework

The conceptual framework assumes that planting method influences vegetative growth parameters (LAI and root length), which in turn affect yield components such as panicle length, grain filling, and grain yield mass. However, rice plants exhibit physiological plasticity, enabling compensation during reproductive stages even when vegetative growth differs.

Statement of the Problem

This study was conducted to assess growth responses and yield of *Oryza sativa* L. on Earthen Pond-based floating Bed System for farm floating culture. Specifically, it sought to (1) analyze the soil quality of the Rice Earthen Pond–based Floating Bed System in terms of pH, potassium, nitrogen, and phosphorus; (2) analyze the water quality of the Rice Earthen Pond–based Floating Bed System in terms of pH level, nitrite, nitrate, and ammonia; (3) determine the growth responses of O. sativa L. in terms of shoot length, leaf length, number of leaves, leaf area index, and root length; (4) determine the yield of *O. sativa* L. in terms of number of productive tillers, length of panicle, 1000-grain weight, percentage of filled and unfilled grains, and grain yield mass; and (5) determine the significant difference in the growth responses and yield of O. sativa L. planted in the Rice Earthen Pond–based Floating Bed System and traditional rice farming.

METHOD

Research Design

This study employed a quantitative–descriptive research design with an experimental approach to evaluate the growth responses and yield performance of *Oryza sativa* L. under two cultivation systems. The independent variable was the cultivation method, consisting of (1) an earthen pond–based floating bed system and (2) a traditional method. The dependent variables included growth parameters (shoot length, leaf length, number of leaves, leaf area index, and root length) and yield parameters (number of productive tillers, panicle length, 1000-grain weight, percentage of filled and unfilled grains, and grain yield mass). A Completely Randomized Design (CRD) was utilized with two treatments, five replications per treatment, and three trials to enhance reliability.

Study Site

The study was conducted in Naci (Doce), Surallah, South Cotabato, Philippines (6°21’40” N, 124°47’33” E), an agricultural area predominantly cultivated with rice and corn. The experiment utilized a 375 m^2 man-made earthen pond supplied with irrigation water from a deep well. Floating plant bed setups (1 × 1.5 m) were installed within the pond and enclosed with net fencing. Data collection and observations were conducted at 30, 60, and 90 days after transplanting (DAT).

Preparation and Selection of Rice Seeds

The rice cultivar used was NSIC Rc160, a high-yielding inbred variety recommended by the Philippine Rice Research Institute and obtained from the Department of Agriculture–Surallah. Seeds were manually selected based on maturity, uniformity, absence of damage, and viability (non-floating during soaking). Approximately 1 kg of seeds underwent pre-germination by soaking in water for 24 hours followed by 24-hour incubation in a moist sack until radicle emergence (1–2 mm). Seedlings were produced using the dapog method, a nursery technique that promotes uniform growth and efficient transplanting. After 15 days, uniform and healthy seedlings (15–20 cm in height, with well-developed roots and no signs of pest or disease damage) were selected for transplantation. The use of 15-day-old seedlings was based on standard recommendations to reduce transplant

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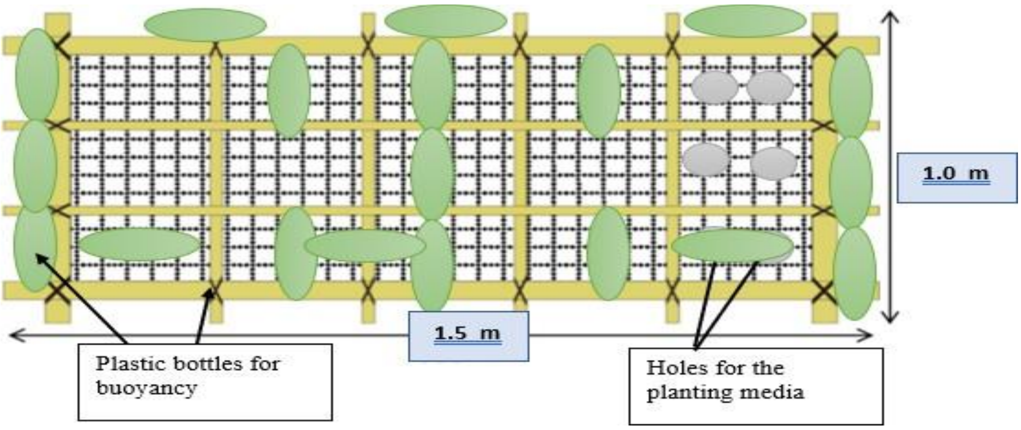
shock and enhance tillering potential.

Floating Bed Construction

The floating raft frame measured 1.5 m × 1.0 m and was constructed from interconnected bamboo pieces secured with tie wire and nails for structural stability. Plastic bottles with caps were attached along the sides and center to ensure buoyancy. The design was adapted from Widodo et al. (2025) with modifications to suit the present study.

Figure 1 The Rice Floating Bed Design Collection of Soil



The planting medium consisted of clay loam soil collected from an active agricultural rice field to ensure realistic production conditions. The same soil source was used for both treatments to control variability. Soil was sieved for uniformity, and 1000 g were placed in each 22-ounce plant pot. In the floating bed treatment, bamboo raft structures with rectangular openings held the pots, with approximately half of each pot submerged in water to allow capillary water movement while preventing excessive waterlogging. Pots were spaced 20 cm apart, and two seedlings were transplanted per pot. The traditional method followed the same soil quantity, spacing, and planting density.

Data Collection Procedure

Chemical Analysis of Soil and water

Prior to the experiment, soil and water samples were collected and analyzed to determine their chemical properties. Soil samples were obtained at a depth of approximately 15 cm, sieved, and assessed for pH, nitrogen (N), phosphorus (P), and potassium (K). Soil pH was measured using a 1:1 soil-to-distilled water suspension and a pH test kit, while N, P, and K were analyzed using a disposable soil test kit based on colorimetric comparison with a standard chart.

Water samples from the pond were collected before transplantation and analyzed for pH, nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). pH was determined using a pH test kit, whereas nitrate, nitrite, and ammonia concentrations were measured using an API freshwater test kit following standard colorimetric procedures, with results expressed in parts per million (ppm).

Growth Responses and Yield

Growth parameters were measured at 30, 60, and 90 days after transplanting (DAT). Shoot height, leaf length, and root length were measured using a ruler; the number of leaves was manually counted; and leaf area index (LAI) was computed using the formula LAI = Leaf Area ÷ Ground Area, with leaf area estimated from measured leaf dimensions. At 90 DAT, yield parameters were assessed. Productive tillers were counted based on panicle presence, panicle length was measured from neck node to tip, 1000-grain weight was determined using a digital weighing scale, and filled and unfilled grains were manually separated to compute percentages. Grain yield mass was obtained by weighing harvested grains.

Statistical Analysis

Data were analyzed using descriptive statistics (mean) and inferential statistics through an Independent Samples t-test to determine significant differences between treatments at $\alpha = 0.05$. Assumptions of normality and homogeneity of variance were examined prior to analysis; when equal variances were not met, Welch's t-test was applied. All statistical analyses were performed using Jamovi software.

RESULTS AND DISCUSSION

Finding 1 Chemical Analysis of Soil

One of the main factors for rice cultivation success is the physicochemical nature of the soil and water. As such, an in, depth study was made to determine the most important parameters: soil pH, soil nutrient (N, P, K) availability, and water quality (water pH and nitrogen compounds and ammonia). The results of this study are here presented and explained.

Table 1 Result of Chemical analysis of soil

Parameter	Result	Interpretation
pH	8.0–9.0	Indicates alkaline soil conditions
Nitrogen (N)	0–10 ppm	Reflects low to moderate nitrogen availability
Phosphorus (P)	80–120 ppm	Indicates high phosphorus availability
Potassium (K)	50–80 ppm	Suggests adequate potassium levels

Alkaline reaction (pH 8.0-9.0) of the soil was reported as per physicochemical analysis (Table 1). The alkaline nature of soil can result in the lowering or reduced availability of some micronutrients, however in well-irrigated nutrient-filled water conditions rice adapted a broad pH range (Huang et al., 2017; Saleem et al., 2023). The nitrogen in the soil varied from 0 to 10 ppm, which was assumed to indicate low to moderate N availability, something that could affect vegetative growth since nitrogen is necessary for leaf development and tillering (Moe et al., 2019).

The P levels as presented in Table were high (80-120 ppm) that is beneficial for root growth, early plant establishment and grain development (Naher, et al., 2018). Likewise, range of 50–80 ppm is considered as sufficient K supply which promotes photosynthesis and stress tolerance and the grain filling process in rice plant (Moe et al., 2019).

Finding 2 Chemical Analysis of Soil

Table 2 Result of Chemical analysis of water

Parameter	Result	Interpretation
pH	7.2–7.6	Indicates neutral to slightly alkaline water.
Nitrate	0 ppm	Indicates absence of nitrate contamination
Nitrite	0 ppm	Reflects good water quality,
Ammonia	0 ppm	Suggests non-toxic water conditions

On the other hand, water quality data shown in Table 2 revealed that water pH was neutral to slightly alkaline

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(7.2- 7.6), thus matching the optimum range of pH for good nutrient uptake and physiological processes of rice plant. Moreover, the water quality was quite good as evidenced by the absence of nitrate, nitrite and ammonia (0 ppm) which means that the risk of nutrient toxicity is minimal and thus, these are very favorable conditions for rice that is grown on floating beds (Rahman et al., 2017).

The findings indicated that the combined soil and water physiochemical parameters were generally suitable for rice cultivation in the earthen pond–based floating bed system as well as in traditional ones which contributed to the observed growth responses and yield performance.

Finding 3 Growth Responses of *O. sativa* L

The following discussion analyzes the growth responses of the floating bed system versus the traditional planting method on rice plant growth and yield by examining key study parameters at 30, 60, and 90 days after transplanting (DAT). The data gathered and results of the statistical analyses are presented here.

Table 3 Mean Growth Parameters at 30, 60, and 90 Days After Transplanting (DAT)

3O DAT			60 DAT		90 DAT	
	Floating Bed	Traditional	Floating Bed	Traditional	Floating Bed	Traditional
Growth Parameters						
Shoot Length	27.4 cm [a]	26 cm [a]	65.6 cm [a]	46.8 cm [a]	99.3 cm [a] *	91.4 cm [a] *
Leaf length	19.3 cm	18.2 cm	45.7 cm *	33.9 cm *	39.4 cm	36.4 cm
Number of Leaves	17	17	29	25	29 *	24 *
Leaf Area Index	0.39 cm^2	0.44cm^2	0.57 cm^2	0.69cm^2	0.95 cm^2*	1.32 cm^2*
Root Length	----	-----	-----	-----	15 cm *	16.6 cm *
* -significant @ 0.05						
a- violation of the assumption of equal variances						

Shoot Length

As presented in Table 3, shoot elongation progressed steadily from 30 to 90 DAT under both cultivation systems. During the early vegetative phase (30 DAT), plants grown in the floating bed (27.4 cm) and the traditional soil-based method (26.0 cm) were statistically comparable ($t = 1.08$, $p = 0.288$), indicating that establishment and initial growth were not influenced by the production system. At this stage, seedling vigor likely played a more dominant role than environmental conditions.

A clear divergence became evident at 60 DAT. The floating bed treatment recorded a substantially greater mean shoot length (65.6 cm) compared with the traditional method (46.8 cm), and this difference was highly significant (Welch's $t = 7.13$, $p < 0.001$). The advantage of the floating bed system persisted at 90 DAT, where plants reached 99.3 cm versus 91.4 cm in the soil-based setup ($t = -3.39$, $p = 0.002$).

These findings suggest that while early shoot development was uniform, the floating bed system enhanced stem elongation during the active tillering and elongation phases, likely due to sustained water contact and improved nutrient diffusion. Thus, its influence became more pronounced as vegetative demand intensified.

Leaf Length

Leaf elongation exhibited a distinct developmental pattern across growth stages (Table 3). At 30 DAT, mean leaf lengths were statistically similar between the floating bed (19.3 cm) and traditional system (18.2 cm) ($t = 1.687$, $p = 0.103$), reflecting uniform early vegetative expansion.

The greatest treatment effect occurred at 60 DAT. Leaves under the floating bed system extended to 45.7 cm, significantly longer than those grown in soil (33.9 cm) ($t = 5.576$, $p < 0.001$). This marked increase during peak vegetative growth suggests that favorable moisture and nutrient conditions enhanced cellular expansion and leaf blade development.

By 90 DAT, however, leaf length no longer differed significantly between treatments (39.4 cm for floating bed; 36.4 cm for traditional; $t = 0.962$, $p = 0.344$). The slight reduction and stabilization in measurements likely reflect the crop's physiological transition toward reproductive development, during which assimilates are increasingly redirected from leaf expansion to panicle formation.

Thus, treatment effects on leaf length were stage-specific, with the floating bed system exerting the strongest influence during mid-vegetative growth.

Number of Leaves

Leaf production followed a cumulative trend across sampling periods (Table 3), increasing consistently from 30 to 90 DAT in both systems. At 30 DAT, both treatments produced an identical mean of 17 leaves ($t = 0.398$, $p = 0.693$), demonstrating that early leaf initiation was unaffected by cultivation method.

Although the floating bed system showed numerically higher leaf counts at 60 DAT (29 leaves) compared with the traditional method (25 leaves), this difference remained statistically non-significant ($t = 1.430$, $p = 0.164$). This indicates that mid-stage leaf initiation was largely governed by varietal characteristics rather than environmental variation.

A significant difference emerged only at 90 DAT ($t = 2.183$, $p = 0.038$), suggesting that treatment effects became more apparent during the late vegetative to early reproductive stage. The delayed statistical response implies that cumulative environmental influences may have gradually contributed to differences in leaf proliferation.

In general, leaf number appeared less sensitive to cultivation system than other growth parameters, with significant variation observed only at the later stage.

Leaf Area Index (LAI)

Canopy development, expressed as Leaf Area Index (LAI), showed a progressive increase from 30 to 90 DAT in both treatments (Table 3). Unlike shoot and leaf length, however, the traditional soil-based system consistently recorded higher LAI values across all stages. At 30 DAT, LAI measured 0.39 in the floating bed and 0.44 in the traditional method. Values rose to 0.57 and 0.69 at 60 DAT, and further increased to 0.95 and 1.32 at 90 DAT, respectively.

Despite these numerical differences, statistical analysis indicated no significant variation at 30 DAT ($t= 1.85$, $p = 0.075$) and 60 DAT ($t = 1.63$, $p = 0.114$). Only at 90 DAT did the difference become significant ($t = 2.49$, $p = 0.019$), with the traditional system exhibiting greater canopy density.

The higher LAI under soil-based cultivation during the later stage suggests enhanced canopy expansion and potentially greater light interception as plants approached reproductive maturity. In contrast, the comparatively moderate LAI values in the floating bed system may indicate a different assimilate allocation strategy, possibly favoring stem elongation and reproductive structures over continued leaf area expansion.

LAI responses highlight that while both systems supported adequate canopy formation, the traditional method promoted denser foliage at advanced growth stages.

Root length

The mean root length of rice plants grown under the two cultivation systems was also assessed at 90 DAT. The traditional method produced a significantly longer mean root length (16.6 cm) compared to the floating bed system (15.0 cm).

Independent samples t-test analysis confirmed that this difference was statistically significant ($t = -2.520$, $df = 28$, $p = 0.018$). This indicates that the cultivation method significantly influenced root development. The shorter root length observed in the floating bed system may be associated with substrate depth and structural limitations. Wu et al. (2013) suggested that floating culture systems may restrict vertical root penetration due to shallow or compact growing media. Furthermore, because floating plants are continuously supplied with water, there is reduced necessity for extensive root elongation for water acquisition (Rahman et al., 2017).

In contrast, conventional soil-based cultivation encourages deeper root growth as plants explore the soil profile for nutrients and water. Huang et al. (2017) reported that rice grown in soil conditions often develops longer roots as an adaptive response to enhance nutrient uptake, particularly nitrogen. Greater root elongation in the traditional system may contribute to improved structural support and nutrient absorption capacity.

The significant differences observed in certain vegetative parameters between the two systems can be attributed to variations in nutrient dynamics, water availability, and plant physiological responses. Water and nitrogen availability are key drivers of vegetative growth, including shoot elongation, leaf expansion, and leaf production (Singh et al., 2025). The floating bed system, which ensures continuous water supply and potentially more uniform nutrient distribution, may explain the enhanced shoot and leaf elongation observed in earlier parameters, despite reduced root extension.

Finding 4 Yield

In order to compare the effects of the rice floating bed and the traditional method on rice productivity, a broad evaluation of major yield parameters was done at 90 DAT. These parameters reflect the overall plant growth and therefore, they play a key role in the prediction of the final grain yield under the given conditions.

Table 4 Mean Results of the Yield of O. sativa L. at 90 DAT

	Planting Method	
Yield Parameters	Floating Bed	Traditional
Number of productive tillers	6.6	6.8
Length of panicle	27.5 cm *	30.4 cm *
1000-grain weight	27.7 g	27 g
Percentage of filled grains	91.90%	93.60%
Percentage of unfilled grains	8.10%	6.40%
Grain yield mass	289 g	283 g
* significant @ 0.05		

Yield components were evaluated to determine the productivity of rice grown under the floating bed and traditional soil-based systems. Overall, most yield parameters were statistically comparable between treatments, indicating similar productive performance.

The number of productive tillers did not differ significantly between the floating bed (6.6) and traditional method

(6.8) (t = 0.346, p = 0.732), suggesting that tiller formation was not influenced by cultivation system. Tiller production in rice has been reported to be strongly influenced by inherent genetic potential, nitrogen availability, and plant density rather than cultivation technique alone (Kumar et al., 2018). Likewise, 1000-grain weight was statistically similar (27.7 g for floating bed; 27.0 g for traditional; t = 0.295, p = 0.783), indicating that grain size and density were largely governed by varietal characteristics and grain-filling efficiency (Zhao et al., 2019).

Grain filling performance was high in both systems. The percentage of filled grains reached 91.9% in the floating bed and 93.6% in the traditional method, while unfilled grains were 8.1% and 6.4%, respectively, with no significant differences (p = 0.236). Efficient assimilate translocation from source to sink during grain filling is critical for high grain fill and is influenced by both genetic and environmental factors (Yang et al., 2016). Similarly, grain yield mass was statistically comparable, with the floating bed producing 289 g and the traditional method 283 g (t = 1.509, p = 0.206). Comparable grain yield under contrasting cultivation systems has been observed in studies evaluating alternative rice production techniques (Hossain et al., 2020).

Among all yield components, only panicle length showed a significant difference, favoring the traditional method (30.4 cm) over the floating bed system (27.5 cm) (t = 3.131, p = 0.004). Panicle elongation is often associated with stronger vegetative canopy development and greater assimilate availability during the reproductive phase (Zeng and Shannon, 2000). Soils with better root anchorage and nutrient buffering capacity may support enhanced panicle growth compared to alternative mediums (Peng et al., 2008).

Overall, despite differences in certain growth traits and panicle length, the floating bed system achieved grain yield levels comparable to conventional cultivation. These findings indicate that the earthen pond–based floating bed system can effectively sustain rice productivity through balanced growth and efficient grain filling, consistent with literature reporting the adaptability of rice to non-traditional cultivation environments (Rahman et al., 2017; Wu et al., 2013).

CONCLUSION

This study compared the growth response and yield performance of *Oryza sativa* L. under an earthen pond–based floating bed system and the traditional soil-based planting method, including the assessment of soil and water chemical properties.

The soil was alkaline, and the water was neutral to slightly alkaline with adequate nutrient levels, which supported proper plant growth in both systems.

Results showed that the floating bed system significantly improved shoot length (60, 90 DAT), leaf length (60 DAT), and number of leaves (90 DAT), while the traditional method resulted in higher leaf area index, longer roots, and longer panicles at 90 DAT. However, most yield parameters—number of productive tillers, 1000-grain weight, percentage of filled and unfilled grains, and grain yield mass—did not differ significantly between the two systems. Although panicle length was greater in the traditional method, the floating bed system achieved comparable grain yield and high grain filling efficiency.

Overall, despite some differences in vegetative growth, the earthen pond–based floating bed system produced yield performance comparable to the traditional method, indicating that it is a viable alternative for rice cultivation. These findings provide scientific evidence that floating bed cultivation can serve as a climate-resilient rice production strategy in flood-affected regions. The study contributes to the growing body of knowledge on alternative rice farming systems and supports the adoption of floating agriculture as a sustainable adaptation measure under changing environmental conditions.

RECOMMENDATION

The earthen pond–based floating bed system is recommended as a viable alternative for rice cultivation, particularly in flood-prone, waterlogged, and land-limited areas where conventional farming is constrained. Given its comparable grain yield and high grain-filling performance, the system demonstrates strong potential for sustaining rice production under challenging conditions.

Further improvement may focus on optimizing substrate composition, nutrient management, and bed design to enhance root development and panicle growth. Regular monitoring of soil and water quality is essential to maintain nutrient balance. Future studies should evaluate long-term yield stability and economic feasibility to support wider adoption.

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