

Growth and Yield Response of Inbred Rice (*Oryza sativa* L.) to Different Levels of Monosodium Glutamate

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ABSTRACT

Monosodium glutamate (MSG) contains nutrients that can influence plant growth and productivity. This study evaluated the growth and yield response of inbred rice (*Oryza sativa* L.) varieties to different levels of MSG. A factorial experiment was conducted using a split-plot arrangement in a Randomized Complete Block Design (RCBD). The main plots consisted of three inbred rice varieties, while the subplots contained three MSG levels and a control. Parameters observed included plant height (20, 40, 60, and 80 DAT), tiller count (20, 40, and 60 DAT), leaf area index (LAI), number of days to heading and flowering, number of productive tillers, panicle length, number of filled and unfilled grains, 1000-grain weight, and grain yield (t/ha). Data were analyzed using the Least Significant Difference (LSD) test at a 0.05 significance level. Results revealed no interaction effect between varieties and MSG levels on most growth traits, but a significant interaction occurred in yield parameters, particularly on NSIC Rc 216 at 5.0 g MSG L⁻¹ of water. Factor A (variety) significantly affected plant height, panicle length, number of unfilled spikelet's, 1000-grain weight, and grain yield, while Factor B (MSG level) influenced plant height, tiller count, LAI, and productive tillers. Cost and return analysis showed NSIC Rc 222 had the highest net income and benefit-cost ratio. The application of 7.5 g MSG L⁻¹ of water increased yield profitability but had limited improvement in cost efficiency

Keywords: *Inbred rice, Monosodium glutamate, Growth response, Yield, Profitability*

INTRODUCTION

Rice or Palay (*Oryza sativa* L.) is the principal staple energy source cereal crop in the Philippines and remains the most politically and economically sensitive agricultural commodity in the country (Department of Agriculture [DA], 2018). According to the report of the Philippine Statistics Authority (2022), approximately 4.86 million hectares of palay land are cultivated nationwide both lowland and upland areas, producing 19.6 million tons with an average yield of 4.04 t ha⁻¹. In Capiz Province, palay

production was range from 348.48 thousand tons in 2017 which increases to 383.81 thousand tons in 2021, reflecting an annual growth rate of 2.03%. Major institutions such as PhilRice, IRRI, the University of the Philippines Los Baños, and private seed companies continuously developed inbred rice varieties that are high-yielding and climate-resilient (Palanog et al., 2020). Among these varieties are PSB Rc 10 (Pagsanjan), which is known for drought tolerance; NSIC Rc 216 (Tubigan 17), adaptable to both wet and dry environments; and NSIC Rc 222 (Tubigan 18), widely cultivated due to its stable yield potential and most preferred by the farmer due to the market and seed availability, and have the dwarf height (PhilRice, 2018).

The unsustainable agricultural practice by farmer and farm workers or locally known as ‘Mamumungon or mangagawa sa bukid’ adversely affect food security, environmental quality, and human health (Sun et al., 2019). Although inorganic fertilizers contribute to high crop productivity, their excessive and prolonged use accelerates soil acidification and degrades soil health (Guo et al., 2010). In addition, rising fertilizer costs limit accessibility among smallholder farmers due to limited financial assets, emphasizing the need to explore affordable and environmentally friendly nutrient alternatives (Mohammad, 2010).

Monosodium glutamate (MSG; $C_5H_8NO_4Na$), commonly used as a flavor enhancer, is the sodium salt of glutamic acid and is highly soluble in water (Lölinger, 2000; Zhang et al., 2012). Glutamate serves as an important nitrogen donor in plants and plays a key role in primary metabolic processes (Krishna & Mohan, 2017; Zhang et al., 2017). Studies have reported that the sodium component of MSG can enhance photosynthetic activity and partially substitute for potassium in plant nutrition (Wakeel et al., 2011), while its nitrogen content promotes vegetative growth (Kraboun et al., 2013). These properties suggest that MSG has potential as an alternative nutrient source for crop production. However, field-based studies evaluating its effects on the growth, yield, and profitability of inbred rice varieties under local conditions remain limited.

This study aimed to evaluate the response of selected inbred rice varieties to different levels of MSG application in terms of growth and yield performance and to assess the profitability of MSG use under field conditions in Capiz, Philippines.

METHODS

Research Design

The experiment followed a 3×4 factorial arrangement in a split-plot design arranged in a Randomized Complete Block Design (RCBD) with three replications. The assignment of treatments and experimental layout followed standard procedures for field experiments with rice as described by Gomez (1972) and Ogunsanya et al., (2016).

The experiment consisted of two factors:

Factor A (Main plot): Inbred rice varieties

- V₁: PSB Rc 10
- V₂: NSIC Rc 216
- V₃: NSIC Rc 222

Factor B (Subplot): Levels of Monosodium Glutamate (MSG)

- T₀: Control (no MSG application)
- T₁: 2.5 g MSG L⁻¹ water
- T₂: 5.0 g MSG L⁻¹ water
- T₃: 7.5 g MSG L⁻¹ water

The layout of the field experiment is presented in Figure 1.

The main plot consisted of inbred rice varieties: V₁ – PSB Rc 10; V₂ – NSIC Rc 216; and V₃ – NSIC Rc 222. The subplot consisted of different levels of MSG: T₀ – Control (no application); T₁ – 2.5 g MSG L⁻¹ of water; T₂ – 5.0 g MSG L⁻¹ of water; and T₃ – 7.5 g MSG L⁻¹ of water.

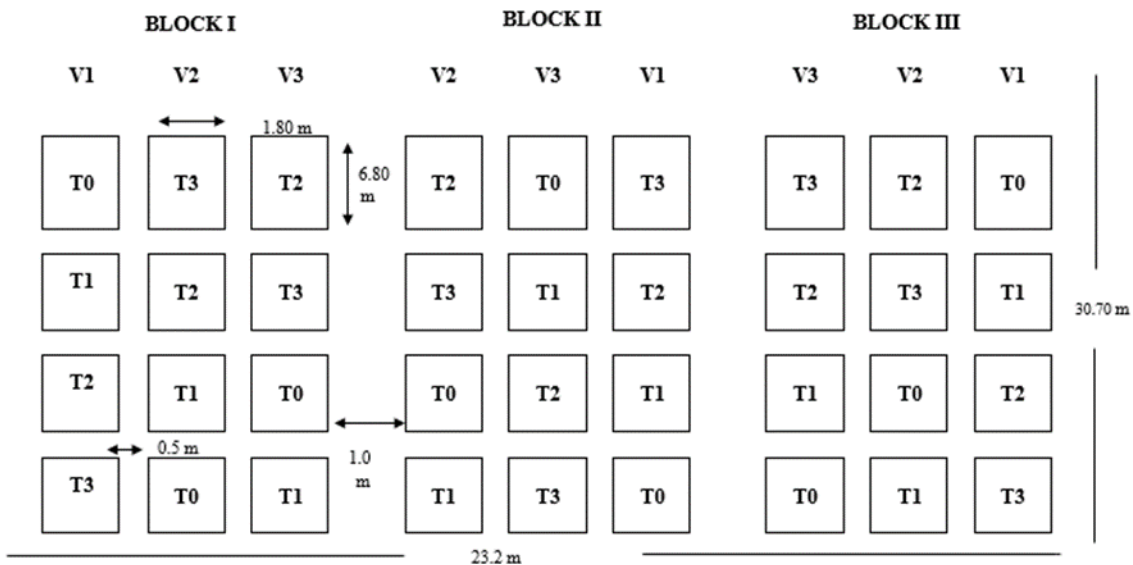


Figure 1. Field layout of the experiment using Split Plot Design arranged in Randomized Complete Block Design (RCBD).

Research Locale

The study was conducted at Barangay Tico, Panay, Capiz, Philippines, from July to November 2023 under irrigated lowland conditions.

Cultural Management Practices

Soil Analysis. Soil samples were collected before land preparation using a soil auger and analyzed at the Capiz State University Soil Laboratory.

Land Preparation. A 712.24 m² irrigated field was plowed and harrowed twice at five- to seven-day intervals. Canals were constructed between plots to ensure proper drainage.

Seedbed and Transplanting. Seeds were soaked, incubated, and raised in nursery beds. Seedlings were transplanted at 14 days after sowing, with a spacing of 20 cm × 20 cm (one seedling per hill).

Pest Management. Pre- and post-emergent herbicides and insecticides were applied as needed following standard cultural practices.

Application of MSG. Foliar spraying was done every 10 days, starting seven days after transplanting, until 80 DAT. MSG was applied according to treatment levels following Awang et al. (2020) and Septinyana et al. (2019).

Water Management. Intermittent irrigation (3–5 cm depth) was maintained during the crop's growth period. Water was drained two weeks before harvest.

Harvesting. Harvesting was performed when grains reached maturity. Panicles were manually cut, threshed, and cleaned.

Data Gathering Procedure

Growth Parameters

Growth parameters were collected from ten (10) randomly selected sample plants per plot, excluding border rows, following standard agronomic procedures.

Plant Height (cm)

Plant height was measured at 20, 40, 60, and 80 days after transplanting (DAT) using a measuring tape attached to a bamboo stick. Measurements were taken from the base of the plant to the tip of the tallest leaf. The mean plant height per plot was computed by averaging measurements from ten sample plants (Dollison, 2023).

Number of Tillers

The number of tillers per hill was counted at 20, 40, 60, and 80 DAT from the same ten sample plants per plot. Mean tiller count was obtained by averaging the total number of tillers per plot (Dollison, 2023).

Days to Heading

Days to heading were determined by counting the number of days from transplanting until approximately 50% of the plants in each plot exerted panicles from the flag leaf (Dollison, 2023).

Days to Flowering

Days to flowering were recorded as the number of days from transplanting until at least 50% of the panicles in each plot showed anthesis (Dollison, 2023).

Leaf Area Index (LAI)

Leaf area index was measured at the heading stage using five (5) randomly selected sample hills per plot. From each hill, the length and maximum width of all leaves from the middle tiller were measured. Leaf area was computed using the formula:

Leaf area=Length×Width×0.75

Total leaf area per hill was calculated by multiplying the leaf area of the middle tiller by the total number of tillers. LAI was computed as:

$$LAI = \frac{\text{Total leaf area of five sample hills}}{\text{Ground area occupied by five hills}}$$

The mean LAI per plot was obtained by averaging the computed values (Baoy & Bañoc, 2017).

Yield Parameters

Yield and yield components were determined at maturity using ten (10) sample plants per plot.

Number of Productive Tillers

Productive tillers were counted as tillers bearing fully developed panicles at harvest.

Panicle Length (cm)

Panicle length was measured from the panicle neck to the tip of the uppermost spikelet using a measuring tape. Mean panicle length was calculated from ten sample plants per plot (Baoy & Bañoc, 2017).

Filled and Unfilled Spikelets

At harvest, panicles from ten sample plants per plot were threshed manually. Filled and unfilled spikelets were separated and counted, and mean values per plot were computed (Baoy & Bañoc, 2017).

Weight of 1000 Grains (g)

One thousand (1000) filled grains were randomly selected from each plot and weighed using a digital weighing scale. The mean 1000-grain weight was recorded (Baoy & Bañoc, 2017; Dollison, 2023).

Grain Yield (t ha⁻¹)

Grain yield was determined by weighing the harvested grains from the harvestable area of each plot and converted to tons per hectare using the formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Plot yield (kg)}}{\text{Harvestable area (m}^2\text{)}} \times \frac{10,000}{1,000}$$

Cost and Return Analysis

Economic analysis was conducted to evaluate the profitability of MSG application following Igdanes and Ratilla (2022). Total production cost was computed by summing all labor, material, and operational expenses. Gross income was calculated by multiplying grain yield by the prevailing farm-gate price of palay. Net income and benefit-cost ratio (BCR) were computed as:

$$\text{Gross income} = \text{Grain yield (kg ha}^{-1}\text{)} \times \text{Price (PHP kg}^{-1}\text{)}$$

$$\text{Net income} = \text{Gross Income} - \text{Total production cost}$$

$$\text{BCR} = \frac{\text{Net income}}{\text{Total production cost}}$$

Data Analysis

All growth, yield, and economic data were subjected to analysis of variance (ANOVA) appropriate for a split-plot Randomized Complete Block Design (RCBD) using the Statistical Tool for Agricultural Research (STAR) software (Gulles et al., 2014). The experimental layout and statistical model for the RCBD and split-plot arrangement followed the procedures described by Gomez and Gomez (1984) and

Mandal et al. (n.d.). Treatment means showing significant differences were compared using the Least Significant Difference (LSD) test at the 5% level of significance (Tenny & Abdelgawad, 2017).

RESULTS AND DISCUSSION

Growth Performance of Inbred Rice

Growth parameters of inbred rice varieties applied with different levels of monosodium glutamate (MSG) are presented in Table 1. Results indicated no significant interaction effect between inbred rice varieties and MSG levels on plant height, tiller count, and leaf area index (LAI) across different growth stages. However, plants treated with 5.0 g MSG L⁻¹ consistently exhibited improved vegetative performance compared with the control, indicating a favorable response to moderate MSG supplementation.

Among the varieties, NSIC Rc 216 and NSIC Rc 222 showed superior vegetative growth compared with PSB Rc 10, which may be attributed to their enhanced genetic traits and adaptability to nutrient-enriched conditions (Hossain et al., 2008; Khatun, 2001). The growth enhancement observed with MSG application may be associated with the role of glutamate as a nitrogen donor that promotes chlorophyll synthesis and enzymatic activity (Wakeel et al., 2011; Kraboun et al., 2013; Noor, 2017; Ghoneim & Ebid, 2015). Likewise, the increase in plant height with MSG application supports the findings of Mohamad (2019), who reported improved vegetative growth following MSG supplementation.

Both nutrient availability and genetic potential may influence the observed variation in tiller number among treatments. Ao et al. (2000) reported that excessive tillering can result in a higher proportion of unproductive tillers, while varietal differences in tiller production are largely governed by genetic potential (Roy et al., 2004). The response of LAI to MSG application may be attributed to foliar nutrient absorption through stomatal uptake (Putra et al., 2014), which enhances photosynthetic capacity and biomass accumulation (Ginandjar et al., 2019).

Overall, these results confirm that MSG, when applied at moderate levels, can enhance vegetative vigor in inbred rice varieties, although such improvements do not always translate into statistically significant differences.

Table 1. Growth Performance of Inbred Rice Varieties as Influenced by Different Levels of Monosodium Glutamate under Field Conditions

Variety	MSG Level (g L ⁻¹)	Plant Height (cm)	Tiller Count (no.)	Leaf Area Index (LAI)
PSB Rc 10	0.0	61.2 ^b	11.8 ^b	2.53 ^b
	2.5	64.5 ^{ab}	12.4 ^b	2.60 ^b
	5.0	66.9 ^a	13.3 ^{ab}	2.74 ^a
	7.5	66.0 ^a	13.0 ^b	2.68 ^a
NSIC Rc 216	0.0	63.8 ^b	12.0 ^b	2.59 ^b
	2.5	67.5 ^a	13.2 ^{ab}	2.75 ^a
	5.0	69.4^a	14.0^a	2.84^a
	7.5	68.5 ^a	13.7 ^a	2.80 ^a
NSIC Rc 222	0.0	62.5 ^b	11.9 ^b	2.57 ^b
	2.5	65.0 ^{ab}	12.5 ^b	2.64 ^b
	5.0	67.0 ^a	13.5 ^a	2.78 ^a
	7.5	66.8 ^a	13.2 ^b	2.72 ^a

Values followed by different letters in a column differ significantly at $p < 0.05$ (LSD test).

Source: Field experiment, Tico, Panay, Capiz, July–November 2023.

Yield and Yield Components

Yield and yield components of inbred rice varieties as affected by different levels of monosodium glutamate (MSG) are presented in Table 2. A significant interaction between rice variety and MSG level was observed for most yield-related parameters, indicating that varietal response to MSG application varied across treatments.

Among the treatments, NSIC Rc 216 applied with 5.0 g MSG L⁻¹ recorded the highest grain yield (5.87 t ha⁻¹), which was significantly higher than most other treatment combinations. This was followed by NSIC Rc 222 at the same MSG level (5.65 t ha⁻¹). The improved grain yield at moderate MSG application was associated with increases in productive tillers, panicle length, number of filled spikelets, and 1000-grain weight.

Productive tiller number was significantly higher in NSIC Rc 216 at 5.0 g MSG L⁻¹ (17.3 tillers hill⁻¹), suggesting a strong varietal response to MSG supplementation. In contrast, PSB Rc 10 and NSIC Rc 222 showed only numerical increases in productive tillers, indicating that tillering capacity was largely influenced by genetic potential rather than MSG level alone. Similar observations were reported by Hossain et al. (2008), who noted that effective tiller production in rice is strongly genotype-dependent.

Panicle length increased significantly with MSG application, particularly at 5.0 g MSG L⁻¹ across all varieties. Longer panicles contributed to a higher number of filled spikelets, especially in NSIC Rc 216

(92.4 spikelets hill⁻¹), which directly enhanced grain yield. This agrees with Cheng et al. (2007), who emphasized that panicle length is a major determinant of grain number and yield in rice.

The number of unfilled spikelets tended to decrease with increasing MSG levels, particularly at moderate application rates. This response may be associated with improved assimilate availability during grain filling, which enhances the fertility of later-flowering inferior spikelets that are otherwise prone to poor filling or sterility (Mohapatra et al., 2021). The highest MSG level (7.5 g L⁻¹), however, did not consistently improve filled spikelet number and slightly reduced grain yield, suggesting possible nutrient imbalance or osmotic stress at excessive MSG concentrations. Similar diminishing yield responses at high nutrient levels were reported by Septiyana et al. (2019).

The 1000-grain weight was significantly higher at 5.0 g MSG L⁻¹, particularly in NSIC Rc 216 (25.7 g), indicating improved grain development and assimilate translocation. Nitrogen supplied through glutamate plays a crucial role in grain formation and grain weight, as reported by Okoye et al. (2006) and Awang et al. (2020).

Overall, the results indicate that moderate MSG application (5.0 g L⁻¹) optimizes yield and yield components, while higher application rates do not provide additional yield benefits. The superior performance of NSIC Rc 216 and NSIC Rc 222 highlights the importance of varietal selection in maximizing the positive effects of MSG supplementation under field conditions.

Table 2. Yield and Yield Components of Inbred Rice Varieties as Affected by Monosodium Glutamate Application Levels

Variety	MSG Level (g L ⁻¹)	Productive Tillers (no.)	Panicle Length (cm)	Filled Spikelets (no.)	Unfilled Spikelets (no.)	1000-Grain Weight (g)	Grain Yield (t ha ⁻¹)
PSB Rc 10	0.0	14.2 ^b	22.1 ^b	78.5 ^b	16.3 ^a	22.5 ^b	4.12 ^c
	2.5	15.0 ^b	23.3 ^{ab}	82.6 ^b	15.2 ^a	23.4 ^b	4.58 ^{bc}
	5.0	16.1 ^b	24.0 ^a	86.3 ^b	13.8 ^b	24.2 ^{ab}	4.95 ^b
	7.5	15.9 ^b	23.7 ^a	85.1 ^b	14.5 ^b	23.8 ^{ab}	4.80 ^b
NSIC Rc 216	0.0	15.5 ^b	23.0 ^b	83.2 ^b	15.0 ^a	23.9 ^b	4.72 ^b
	2.5	16.2 ^b	24.3 ^a	87.6 ^b	13.2 ^b	24.5 ^a	5.30 ^b
	5.0	17.3^a	25.1^a	92.4^a	11.4^b	25.7^a	5.87^a
	7.5	16.8 ^b	24.7 ^a	90.8 ^a	12.3 ^b	25.2 ^a	5.65 ^{ab}
NSIC Rc 222	0.0	14.7 ^b	22.9 ^b	79.3 ^b	15.5 ^a	23.1 ^b	4.41 ^{bc}
	2.5	15.5 ^b	23.6 ^a	84.8 ^b	13.8 ^b	24.0 ^{ab}	4.95 ^b
	5.0	16.4 ^b	24.4 ^a	88.9 ^{ab}	12.1 ^b	24.8 ^a	5.65 ^{ab}

7.5 16.0^b 24.0^a 87.3^b 13.0^b 24.5^a 5.42^b

Values followed by different letters in a column differ significantly at $p < 0.05$ (LSD test).

Source: Field experiment, Tico, Panay, Capiz, July–November 2023.

Economic Analysis

The benefit–cost ratio (BCR) is a key profitability indicator used to assess the economic viability of agricultural production systems by comparing net returns relative to total production costs (Devarakonda, 2019). The cost and return analysis of inbred rice varieties under different levels of monosodium glutamate (MSG) application is presented in Table 3. Results showed that NSIC Rc 222 applied with 5.0 g MSG L⁻¹ recorded the highest benefit–cost ratio (1.96), indicating superior economic efficiency. Meanwhile, NSIC Rc 216 × 5.0 g MSG L⁻¹ generated the highest net income (₱38,900 ha⁻¹) due to its higher grain yield despite relatively higher production costs.

Although increasing MSG levels generally improved yield performance, the highest application rate (7.5 g MSG L⁻¹) did not consistently result in higher profitability, as the additional input costs reduced net returns and BCR values. This indicates that moderate MSG application (5.0 g L⁻¹) provides a more favorable balance between yield enhancement and cost efficiency. Similar findings were reported by Igdanes and Ratilla (2022), who emphasized the importance of optimizing input use to maximize farm profitability.

Variations in net income among treatments can also be influenced by biotic and abiotic factors, which affect crop growth, yield stability, and production costs (Liliane & Charles, 2020). In addition, genotypic differences among rice varieties contribute to variability in yield potential and economic performance (Yang & Hwa, 2008). This supports the findings of Hussain et al. (2014), who reported that crop genotypes play a dominant role in determining productivity and profitability under different management and environmental conditions.

Table 3. Economic Analysis of Inbred Rice Production Using Different Levels of Monosodium Glutamate

Variety	MSG Level (g L ⁻¹)	Grain Yield (t ha ⁻¹)	Gross Income (₱ ha ⁻¹)	Total Cost (₱ ha ⁻¹)	Net Income (₱ ha ⁻¹)	BCR
PSB Rc 10	0.0	4.12	61,800	43,000	18,800	1.43
	2.5	4.58	68,700	45,000	23,700	1.52
	5.0	4.95	74,300	46,500	27,800	1.59
	7.5	4.80	72,000	48,000	24,000	1.50
NSIC Rc 216	0.0	4.72	70,800	43,200	27,600	1.64
	2.5	5.30	79,500	45,500	34,000	1.75
	5.0	5.87	88,000	49,100	38,900	1.78
	7.5	5.65	84,600	51,000	33,600	1.66

NSIC Rc 222	0.0	4.41	66,200	42,900	23,300	1.54
	2.5	4.95	74,300	45,200	29,100	1.64
	5.0	5.65	84,600	47,200	37,400	1.96
	7.5	5.42	81,300	49,000	32,300	1.66

Note: Prices based on prevailing farm-gate value of ₱15.00 kg⁻¹ (2023).

Source: Field experiment, Tico, Panay, Capiz, July–November 2023.

Implications of the Findings

Overall, the study demonstrated that moderate application of monosodium glutamate (MSG) at 5.0 g L⁻¹ can improve yield and economic returns of inbred rice varieties without adversely affecting vegetative growth. The absence of significant interaction effects on growth parameters indicates that varietal responses were primarily governed by genetic potential, while MSG functioned as a supplemental nutrient rather than a dominant growth regulator. The yield and economic advantages observed at 5.0 g MSG L⁻¹ highlight its potential as a low-cost nutrient supplement in rice production systems, particularly for smallholder farmers facing high fertilizer costs and limited access to conventional inputs.

CONCLUSION

The results of the study confirmed that the application of monosodium glutamate (MSG) can enhance the yield and profitability of inbred rice varieties under field conditions in Tico, Panay, Capiz. Although MSG did not significantly influence early growth parameters, the 5.0 g MSG L⁻¹ treatment consistently improved yield components such as productive tillers, panicle length, number of filled spikelets, and 1000-grain weight. Among the varieties evaluated, NSIC Rc 216 and NSIC Rc 222 exhibited superior performance compared with PSB Rc 10, reflecting stronger genetic responsiveness to supplemental nutrient application.

Economic analysis showed that NSIC Rc 216 treated with 5.0 g MSG L⁻¹ generated the highest net income, while NSIC Rc 222 applied with the same MSG level achieved the highest benefit–cost ratio, indicating both productivity and economic efficiency. Increasing the MSG rate to 7.5 g L⁻¹ did not provide additional yield or economic benefits and resulted in diminishing returns. Based on these findings, MSG applied at 5.0 g L⁻¹ may be considered an effective and economical supplemental nutrient source for improving rice productivity, provided it is integrated with appropriate nutrient management practices. Further studies are encouraged to assess MSG application under different seasons, fertilizer combinations, and rice ecosystems, as well as to evaluate its long-term physiological and soil-related effects.

REFERENCES

- Awang, H., Aziz, A. S., Azmi, N. N. A. R., Saad, N. S., Zamri, N. A. S., & Seman-Kamarulzaman, A. F. (2020). Effect of monosodium glutamate on the growth of *Solanum melongena*. *Gading Journal for Science and Technology*, 3(1), 52–59.
- Ao, H., Peng, S., Zou, Y., Tang, Q., & Visperas, R. M. (2010). Reduction of unproductive tillers did not increase the grain yield of irrigated rice. *Field Crops Research*, 116(1–2), 108–115. DOI: <https://doi.org/10.1016/j.fcr.2009.12.003>
- Ayob, A. (2019). Effects of bokashi and application of monosodium glutamate (MSG) as foliar fertilizer on selected soil characteristics and growth performance of pak choy (*Brassica rapa* subsp. *chinensis*) (Doctoral dissertation, Universiti Malaysia Kelantan).
- Baoy, R. R., & Bañoc, D. M. (2017). Growth and yield performance of inbred and hybrid rice varieties as influenced by combined application of organic and inorganic fertilizers. *Annals of Tropical Research*, 39(1), 70–86.
- Cheng, F. M., Zhang, Q. F., Zhu, H. J., Zhao, N. C., Wang, F., Chen, K. M., & Zhang, G. P. (2007). Differences in amylose content within a panicle as affected by panicle morphology of rice cultivars. *Journal of Cereal Science*, 46(1), 49–57. DOI: <https://doi.org/10.1016/j.jcs.2006.11.005>
- Department of Agriculture. (2018). *The Philippine rice industry roadmap 2030: Toward a rice-secure Philippines*.
- Devarakonda, S. (2019). Calculating the economic viability of corporate trainings using benefit–cost ratio (BCR) and return on investment (ROI). *International Journal of Advanced Corporate Learning*, 12(1), 41–57. DOI: <https://doi.org/10.3991/ijac.v12i1.9735>
- Dollison, M. D. (2023). Comparative yield performance of rice production under organic and inorganic fertilizer application. *International Journal of Multidisciplinary: Applied Business and Education Research*, 4(7), 2173–2179. DOI: <https://doi.org/10.11594/ijmaber.04.07.02>
- Ghoneim, A. M., & Ebid, A. I. (2015). Combined effects of soil water regimes and rice straw incorporation on nutrient uptake and rice yield. *International Journal of Plant & Soil Science*, 5(6), 339–349. DOI: <https://doi.org/10.9734/IJPSS/2015/15472>
- Ginandjar, S., Frasetya, B., Nugraha, W., & Subandi, M. (2019). Effect of liquid organic fertilizer from vegetable waste on strawberry growth and yield. *IOP Conference Series: Earth and*

- Environmental Science*, 334.
DOI: <https://doi.org/10.1088/1755-1315/334/1/012033>
- Gomez, K. A. (1972). *Techniques for field experiments with rice*. International Rice Research Institute.
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons.
- Guo, J. H., Liu, X. J., Zhang, Y., Shen, J. L., Han, W. X., Zhang, W. F., & Zhang, F. S. (2010). Significant acidification in major Chinese croplands. *Science*, 327(5968), 1008–1010.
DOI: <https://doi.org/10.1126/science.1182570>
- Gulles, A. A., Bartolome, V. I., Morante, R. I. Z. A., Nora, L. A., Relente, C. E. N., Talay, D. T., & Ye, G. (2014). Randomization and analysis of data using STAR (Statistical Tool for Agricultural Research). *Philippine Journal of Crop Science*, 39(Suppl. 1).
- Hossain, M. B., Islam, M. O., & Hasanuzzaman, M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice varieties. *International Journal of Agriculture and Biology*, 10(6), 693–696.
- Hussain, S., Fujii, T., McGoey, S., Yamada, M., Ramzan, M., & Akmal, M. (2014). Evaluation of rice varieties for growth and yield characteristics. *Journal of Animal and Plant Sciences*, 24(5), 1504–1510.
- Igdanes-Marañan, G. C., & Ratilla, B. C. (2022). Growth and yield response of lowland rice to planting density and nutrient management. DOI:<https://doi.org/doi.org/10.32945/atr44210.2022>
- Khatun, R. (2001). Effect of variety and nitrogen on the performance of fine rice (Master's thesis, Bangladesh Agricultural University).
- Kraboun, K., Tochampa, W., Chatdamrong, W., & Kongbangkerd, T. (2013). Effect of monosodium glutamate on antioxidant activity of waxy corn. *International Food Research Journal*, 20(2).
- Liliane, T. N., & Charles, M. S. (2020). Factors affecting crop yield. *Agronomy – Climate Change & Food Security*.
DOI: <https://doi.org/10.5772/intechopen.90672>
- Löliger, J. (2000). Function and importance of glutamate for savory foods. *Journal of Nutrition*, 130(4), 915S–920S.
DOI: <https://doi.org/10.1093/jn/130.4.915S>
- Mandal, B. N., Parsad, R., & Dash, S. (2024). Split-plot designs with main plot treatments in incomplete blocks. *Statistics and Applications*, 22(3), 243–257.

- Mohamad, M. A. (2019). The effects of monosodium glutamate as an alternative fertilizer on *Zea mays*. *Gading Journal for Science and Technology*, 2(2), 1–7. URI: <https://ir.uitm.edu.my/id/eprint/31166/>
- Mohapatra, P. K., & Sahu, B. B. (2021). Hormonal regulation of spikelet development. In *Panicle architecture of rice and its relationship with grain filling*. Springer. DOI: https://doi.org/10.1007/978-3-030-67897-5_11
- Mursilati, M., Suprpto, A., & Novianto, E. D. (2023). Effect of MSG and liquid organic fertilizer on leaf area and tuber weight of *Canna edulis*. *AIP Conference Proceedings*, 2586. DOI: <https://doi.org/10.1063/5.0106609>
- Palanog, A. D., et al. (2020). Rice breeding strategies in the Philippines. *Journal of Scientific Agriculture*, 4, 21–27. DOI: <https://doi.org/10.25081/jsa.2020.v4.6164>
- Ogunsanya, B. G., & Sulaimon, M. O. (2016). Application of randomized complete block design to the yield of maize. *International Journal of Research*, 3(12).
- Philippine Rice Research Institute. (2018). *NSIC Rc 216 variety profile*. URL: <https://www.philrice.gov.ph>
- Philippine Rice Research Institute. (2018). *Rc 222 boosts yield by 20 cavans*. URL: <https://www.philrice.gov.ph>
- Yang, X. C., & Hwa, C. M. (2008). Genetic modification of plant architecture in rice. *Heredity*, 101(5), 396–404. DOI: <https://doi.org/10.1038/hdy.2008.90>
- Zhang, D., Feng, X., Zhou, Z., Zhang, Y., & Xu, H. (2012). Economical production of poly- γ -glutamic acid. *Bioresource Technology*, 114, 583–588. DOI: <https://doi.org/10.1016/j.biortech.2012.02.114>
- Zhang, L., Yang, X., Gao, D., Wang, L., Li, J., Wei, Z., & Shi, Y. (2017). Effects of poly- γ -glutamic acid on plant growth. *Scientific Reports*, 7, 6090. DOI: <https://doi.org/10.1038/s41598-017-06248-2>