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Water and Nutrient Management Techniques in Rice (*Oryza sativa* L.) Production

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Abstract
Aim: The study aimed evaluated the effectiveness of various water and nutrient management in resource use efficiency in rice production specifically on growth performance, yield, water and nutrient use efficiency, and return on investment.
Methodology: At Cauayan City, Isabela, Philippines, a total of 27 plots were allotted to 2 factor treatments in a Randomized Complete Block Design (RCBD) with three replications. This includes Factor A: Water Management, A1 Continuous flooding, A2 Rainfed, and A3 Alternate Wetting and Drying (AWD) and Factor B: Nutrient Management B1 Organic fertilizer, B2 combination of 50% Organic fertilizer and 50% of recommended Inorganic fertilizer, and B3 Organic fertilizers (100%).
Results: Results showed that the individual and combined effects of water and nutrient management techniques were not significantly affects the plant height, number of productive tillers per hill, root length, and spikelet fertility. However, alternate wetting and drying significantly increased rice grain yield. Organic fertilizers increased nitrogen use efficiency while inorganic fertilizers enhanced phosphorus use efficiency. Also, water and nutrient management enhanced potassium efficiency. Rainfed conditions combined with organic fertilizer had the highest yield. In contrast, alternate wetting and drying combined with organic fertilizers had higher economic benefits. The alternate wetting and drying (AWD) technique increased rice output while nutrient management improved yield and nutrient use efficiencies.
Conclusion. These findings suggest alternate wetting and drying (AWD) and integrated nutrient management (INM) techniques increased yield and nutrient use efficiencies, while rainfed conditions combined with organic fertilizer had a high return on investment.
Keywords: *Continuous flooding, Rainfed, Alternate Wetting and Drying, Resource Use Efficiency*

INTRODUCTION

Rice is a staple food for over half of the world's population (Park et al., 2023). Demand is expected to increase by 56% by 2050 (Islam et al., 2022), worsening water shortages and resource competitiveness in many locations (Tuong & Bouman, 2003; Mekonnen & Hoekstra, 2016).Rice cultivation has traditionally been characterized as water, chemical, and nutrient-intensive (De Fraiture et al., 2014; Mueller et al., 2012) but increasingly challenged by water scarcity or stress, nutrient depletion and inefficient nutrient use, and environmental degradation, which causes terrestrial degradation. Adequate water and nutrient management is essential for rice growing (Duan et al., 2024; Jiao et al., 2016). Several new management practices have been developed to enhance water and nutrient use efficiency while reducing adverse environmental effects (Liu et al., 2019; Subedi & Poudel, 2021).

Integrated crop management systems integrating water and nutrient techniques increase productivity and reduce inputs. The utilization of organic and inorganic, or a combining the two alongside water management techniques such as continuous flooding, rainfed, and alternate wetting and drying, has the potential to improve resource use effectiveness by promoting nutrient uptake, root activity, and nutrient use efficiency (Nkebiwe et al., 2016; Dong et al., 2020). Water-saving technology provides a practical and promising solution to the growing global water scarcity constraints by reducing water consumption, improving water productivity, and increasing crop yields. The study aims to evaluate the effectiveness of varied nutrient management combined with water-saving technologies in increasing rice yields and resource efficiency. Despite the potential benefits, there is limited comprehensive research on the combined effects of various techniques. Addressing these challenges contributes to the United Nations Sustainable Development Goals or SDGs by ensuring food security and nutrition (SGD 2), promoting sustainable water management

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(SDG 6), encouraging efficient resource utilization and reducing environmental impacts (SDG 12), mitigating climate change through sustainable agricultural practices (SDG 13), and protecting terrestrial ecosystems and promoting sustainable land management (SDG 15).

Objectives of the Study

This study evaluated the effectiveness of various water and nutrient management techniques in resource use efficiency in rice production.

It specifically aimed to:

1. investigate water and nutrient management techniques that promote growth, maximize grain yield, and improve water and nutrient use efficiency; and
2. determine which combination of water and nutrient management techniques yields the highest return on Investment (ROI).

METHODS

Procurement of Seeds

A rice variety of LP 2096 was secured and purchased in a reputable agricultural supply store or seed producer.

Soil Sampling and Analysis

A total of 12 soil samples were randomly collected within the experimental area using a shovel before land preparation. The soil samples were spread in a clean sack, pulverized, air dried, and removed inert material. For analysis, a one-kilogram composite soil sample was submitted to the Integrated Soils Laboratory – Department of Agriculture, Cagayan Valley Research Center, San Felipe, City of Ilagan, Isabela.

Land preparation

The land was thoroughly cleaned and plowed before seeding. The land was harrowed and leveled to create a smooth and even planting space

Construction of Plots and Levees

Twenty-seven experimental plots were constructed, measuring 3.2 meters by 3.2 meters. These plots were separated by a 0.75-meter alleyway between blocks and 0.75-meter between individual plots. The levees were constructed with a height of 15 – 20 centimeters. A one-meter-wide space weasel around each block and a levee was constructed to create a barrier and prevent water from seeping into or out of the blocks.

Seeds and Seedling Preparation

The seeds were soaked for 36 hours. The seeds were rinsed with clean water and placed in a cloth and incubated for 36 hours. Sowed the pre-germinated seeds directly into the prepared seedbed.

Installation of PVC pipe for Alternate Wetting and Drying

A total of twenty-seven (27) polyvinyl chloride pipes measuring 15 cm in diameter were perforated with multiple holes to facilitate water flow. These pipes were inserted into the soil to a depth of 15 cm, leaving approximately 10 cm above ground.

Schedule of Alternate Wetting and Drying

Generally, alternate wetting and drying was employed when the water level in the soil drops to zero, indicating the soil has dried out.

Transplanting/Replanting

A 21-year-old seedling was carefully transplanted with two to three seedlings per hill with a planting distance of 20 cm between hills and rows. Replanting was done after five days to replace missing or weak seedlings.

Application of Fertilizer

The application of fertilizers was based on the result of soil analysis following the recommended rate and schedule.

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Experimental Treatments and Design

The experimental plots were randomly distributed into nine (9) treatments. Each treatment was replicated three (3) times with twenty-seven (27) experimental plots. Each block (Factor A) contains three (3) nutrient management techniques and is replicated three (3) times. The experiment was composed of two (2) factors, namely:

Factor A. Water Management

A_1 – Continuous Flooding (5cm water level throughout the production)
A_2 – Rainfed (No irrigation except rainfall)
A_3 – Alternate Wetting and Drying (AWD)

Factor B. Fertilizer Management

B_1 – Organic Fertilizer Application (100% RR)
B_2 – Combined Inorganic and Organic Fertilizer (50% O + 50% NPK-RR)
B_3 – Inorganic Fertilizer Application (RR)

Care and Management

The occurrence of pests such as golden apple snails, insect pests, and bacterial leaf streaks was controlled with synthetic chemicals following the recommended rate.

Harvesting

Harvesting was done when rice grains turned into a golden yellow, and clusters of grains are heavy.

Data Gathered

1. Plant height. The height of the ten sample plants was measured and recorded before harvest.
2. Number of productive tillers per hill. The number of productive tillers per hill of ten sample plants was counted and recorded before harvest.
3. Root length. The length of the root of the ten sample plants was measured and recorded after harvest.
4. Spikelet Fertility. The spikelet fertility of the ten sample was determined by dividing the number of filled spikelets by the number of spikelets per panicle multiplied by 100.
5. Yield per Hectare. The harvested rice grains per plot were dried, weighed, and accurately recorded.
6. Resource Use Efficiency. These were calculated based on the following formula:

a. $$\text{Nitrogen Use Efficiency} = \frac{\text{Grain Yield kg/ha}}{\text{Nitrogen Applied kg/ha}}$$

b. $$\text{Phosphorus Use Efficiency} = \frac{\text{Grain Yield kg/ha}}{\text{Phosphorus Applied kg/ha}}$$

c. $$\text{Potassium Use Efficiency} = \frac{\text{Grain Yield kg/ha}}{\text{Potassium Applied kg/ha}}$$

d. $$\text{Water Use Efficiency} = \frac{\text{Grain Yield kg/ha}}{\text{Water Applied m}^3\text{/ha}}$$

To be able to calculate the volume of water and fertilizer applied, the following formula was used:

Volume of water applied(m3) = area (m2) height of the applied water(m)
Amount of Fertilizer Applied =Application rate x area

e. Economic Use Efficiency. This was calculated based on the following formula:

Gross Income = (Grain yield kg/ha) *(Price of rice/kg)
Net Income = Gross Income – Total cost of production
Return on Investment = (Net profit/Initial investment) * 100

Discussion of Results

A. Growth Performance as Affected by Different Water and Nutrient Management Techniques.

Plant height (cm). The effect of various water and nutrient management techniques on plant height was presented in Table 1. The results revealed that neither the water management (Factor A) nor the nutrient management (Factor B) significantly affected plant height. The highest plant height was observed on

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continuous flooding (A1) and inorganic fertilizer (B3), with an average of 107.65 and 106.96 cm, respectively. The interaction between water and nutrient management was insignificant in all treatment combinations. The effect of each factor on plant height was not dependent on each other.However, the table shows that continuous flooding applied with inorganic fertilizers (A1B1) resulted in the highest plant height 113.02 cm.

Number of Productive Tillers per Hill. The data shows no significant effects on the number of productive tillers of each of the factors. In water management, the highest number of productive tillers was observed on alternate wetting and drying (A1) with a mean of 11.59, followed by rainfed (A2) conditions with 11.58. The lowest number of productive tillers was recorded on continuous flooding (A1), with a mean of 11.09. The data revealed that a combined (Organic Fertilizer 50% + Inorganic Fertilizer 50%) (B2) had the highest with a mean of 11.77 productive tillers, followed by the application of Inorganic Fertilizer (NPK-RR) (B_3) with a mean of 11.3. The lowest number of productive tillers was observed in the sole application of organic fertilizer (B_1). The analysis of variance also showed no significant differences among all treatment combinations, which means that the treatments did not affect the number of tillers. Numerically, the highest number of productive tillers were recorded in treatments combination of A_3B_1 with a mean of 12.47 and the lowest was observed on A_1 B_1, with a mean of 10.53.

Root Length (cm). The influence of different water and nutrient management techniques on root length is presented in Table 1. The result of the variance analysis for water and nutrient management, including the interaction of the two factors, showed no significant differences. The highest length of roots was observed in A3 at 19.36 cm, followed by A2 with a mean of 18.98 cm. The lowest root length was recorded in A_1, with an average of 17.95 cm. On varied nutrient management techniques, the highest length was measured on B_2 with 19.38 cm, followed by B_1 with a mean of 19.16 cm. The lowest was recorded in B_3, with a mean of 17.75 cm. However, treatment combinations (Factor A x B) did not show a combined effect in this study. The highest length was recorded in A3B1 with a mean of 20.51. This conforms to the findings of researchers that a deeper root system was associated with alternate wetting and drying (Al-Juthery *et al.,* 2021), and organic fertilizer can stimulate root growth (Wei *et al.,* 2016).

Spikelet Fertility (%). The result presented in Table 1 showed no significant difference effect on spikelet fertility in both individual factors. For water management, A1 slightly showed a higher spikelet fertility with a mean of 90.09% compared to A3 with 89.31 % and A2 with a mean of 89.16 %. In nutrient management, B3 had the highest mean spikelet fertility at 90.48 %, followed by B1 and B2 with 89.68 and 88.41%, respectively. Treatment combinations between water and nutrient management showed no significant differences. The individual combinations showed no variation based on mean values. The treatment combination A1B3 resulted in relatively high spikelet fertility of 93.77%, while A1B2 showed lower fertility at 86.23 %.

B. Yield Performance as Affected by Different Water and Nutrient Management Techniques

Yield per Hectare(kg). Table 2 presents the yield per hectare as influenced by varying water and nutrient management techniques. Significant results were observed among the experimental treatments in water management. Taken individually, A3 had the highest yield of 8658.86 kg ha-1, followed by A2 and A1 with comparable means of 7508.68 and 7085.50 kg ha-1, respectively. This result aligns with the findings that alternate wetting and drying increased yield (Zhang et al. 2009; Ye et al., 2013; Zhang et al., 2020; Chu et al., 2017) compared with continuous flooding. Also, researchers have reported that alternate wetting and drying can reduce water usage by approximately 43% without compromising yield (Dong et al., 2020; Lampayan et al., 2015; Carrijo et al., 2017). No significant differences were observed between the individual factors in nutrient management. Treatment B2 had resulted in a slightly higher yield with a mean of 7996.96 kg ha-1 compared to B1 and B3 with an average yield of 7931.86 kg ha-1 and 7324.22 kg ha-1, respectively. The interaction effect of the two factors also showed no significant differences. The highest yield was observed on A3B2 with a mean of 9602.87 kg ha-1. This aligns with the findings of Hashim *et al.* (2023), who stated that the interaction between organic and inorganic fertilizers enhances biomass and grain yields of rice and Maneepitak et al. (2019) and Zhou et al. (2017) reported that alternate wetting and drying can increase rice yields compared to traditional irrigation practices.

C. Nutrient Use Efficiency as Affected by Different Water and Nutrient Management Techniques.

Nitrogen Use Efficiency (Kg/N Applied). There was no significant effect of the water management treatments on nitrogen use efficiency was presented in Table 3. The factor A3 had the heaviest yield per

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nitrogen (N) applied, with a mean of 216.03 kg compared to A2 and A1, with an average weight of 200.91 and 176.63 kg, respectively. This result aligns with the suggestions and observations of Soliman et al. (2024) that alternate wetting and drying alongside integrated nutrient management can further enhance nutrient retention and efficiency. The various nutrient management techniques showed highly significant effect on nitrogen use efficiency. The factor B1 was significantly better with a grain weight of 417.47 kg N-1 applied over B2and B3 with 115.06 kg N-1 and 61.04 kg N-1 applied. The plants treated with sole organic fertilizer had the heaviest grains and, hence, the highest nitrogen use efficiency. According to Liu et al. (2020), adding organic fertilizers reduced nitrogen losses and increased nutrient use in rice plants. It also increases microbial community, a critical component for the release of nutrients and utilization (Liu et al., 2019). The results showed that the interaction of the two factors (A x B) did not significantly affect nitrogen use efficiency. Despite statistical insignificance, however, it was recorded that the highest nitrogen use efficiency (NUE) was achieved in A3B1 at 443.73 kg N-1 applied. A similar result was noted by Lv et al. (2023) where they stated that partial substitution of inorganic fertilizer with organic fertilizer had a significant increase in nitrogen use efficiency. The factor combination of A2B1 closely followed with a mean of 442.02 kg N-1 applied. The nitrogen efficiency is consistently low in the treatment combinations applied with inorganic fertilizers.

Phosphorus Use Efficiency (Kg/P Applied). The result revealed no significant variations as affected by the water management techniques was presented in Table 3. The treatment A3 had the highest mean of phosphorus use efficiency (PUE) with 494.73 kg P-1 applied, and this was followed by the factor under rainfed conditions (A2) with a mean of 428.01 kg P-1 applied and A1 at 383. 45 kg P-1 applied. Highly significant variations on phosphorus use efficiency under varied nutrient management conditions. Inorganic Fertilizer (B3) application had the highest harvested grains with a mean of 732.42 kg P-1 applied, followed by combined (Organic Fertilizer 50% + Inorganic Fertilizer 50%) (B2) with a mean of 363.76 kg P-1. The lowest was observed on Organic fertilizer (B1) with a mean of 210.00 kg P-1applied.

The interaction between Factor A and B on phosphorus use efficiency was not statistically significant, and the result shows that A3B3 had the heaviest weight of harvested grains at 794.27 and A1B1 had the lowest phosphorus use efficiency of 126.66 kg P-1 applied. This aligns to the findings of IRRI (2023) that alternate wetting and drying improved nutrient use.

Potassium Use Efficiency (Kg/K Applied). Table 3 presents the result of potassium use efficiency. The result showed that A3 a had significantly higher potassium use efficiency of 152.33 over A1 and A2, which had 132.40 and 124.52 kg K-1 applied, respectively. This observation is similar with the findings of Sardans and Peñuelas (2021), who noted that water availability plays a critical role in nutrient release, affecting nutrient absorption efficiency and the availability of essential nutrients like potassium in crops and alternate wetting and drying optimized this process leading to enhanced potassium uptake and utilization. Palansooriya et al. (2023) they also stated that inefficient or excessive water can limit nutrient release and transformation, limiting nutrient absorption availability. Highly significant variations were also observed in potassium use efficiency as influenced by the different fertilizer applications. B1 had significantly higher potassium use efficiency of 146.89 kg K-1 applied over plots applied with inorganic fertilizer and comparable with plots applied with a combination of organic and inorganic fertilizer.

The interactions of the two treatments in potassium use efficiency resulted no significant differences. However, A3B2 had the highest potassium use efficiency with 168.47 kg K-1 applied and closely followed by A3B1 and A2B1, with a mean of 156.13 and 155.53 kg K-1 applied, respectively. The result aligns with the observation of Soliman et al. (2024) who stated that there is a synergistic effect of alternate wetting and drying combined with integrated nutrient application, which, when implemented had better nutrient utilization.

D. Water Use Efficiency as Affected by Different Water and Nutrient Management Techniques.

Water Use Efficiency (Kg/m^3 Applied). Table 4 presents the result showed highly significant effect of the different management techniques on Water Use Efficiency. Rainfed (A2) conditions had the highest average of 3.75 kg/m3 of water applied compared to alternate wetting and drying (A3) at 2.44 kg/m3 of water applied and Continuous Flooding (A1) with 1.54 kg/m3 of water. Rainfed conditions effectively used water to produce yield per unit of water applied, whereas Alternate wetting and drying (A3) were more efficient than continuous flooding (A1). Also, results showed no significant effect of the different nutrient management techniques on water use efficiency. The mean value across varied nutrient management was comparable. The highest means was recorded in B1 (Organic Fertilizer 100%), followed by B2 (Combined organic fertilizer 50% + Inorganic Fertilizer 50%). The lowest weight was treated with Inorganic Fertilizer

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(B1) with a mean of 2.45 Kg/m3 of water. Applying organic fertilizer significantly improved soil structure, porosity, and water retention (Pandey and Shukla, 2006; Lal et al., 2020; Liu et al., 2023).

The analysis of variance also showed insignificant interactions between the two factors (A and B) on water use efficiency. Numerically, A2B1 (Rainfed with Organic Fertilizer (100%) had the highest water use efficiency at 4.20 Kg/m3 of water. Throughout all nutrient strategies, continuous flooding was consistently low. When combined with organic fertilizers, the result of the rainfed system may enhance the amount of water accessible for plant use, hence increasing water holding capacity (Putri et al., 2023).

E. Cost and Return Analysis of Rice Production (One Hectare) as Affected by Different Water and Nutrient Management Techniques

Cost and Return Analysis. The treatment combination of B1 generally has the lowest costs, ranged from Php. 53600.92 to Php. 55,724.94. The B2 was recorded as intermediate, ranged from Php. 63289.71 to Php. 67844.15. The highest production costs were associated with B3 ranged from Php. 71695.81 to Php. 74517.43 respectively. A3B2 generated the highest gross income, while A2B1 had the highest net income of Php. 67,599.64 which is close to A3 with Php. 66,524.42. The A1 across nutrient management techniques consistently had lower gross and net incomes. The highest return on investment obtained in A2B1 with 124.77 percent. The lowest return on investment was recorded under A1B3 at 38.37 percent.

Table 1. Growth Performance at Different Water and Nutrient Management Techniques.

TREATMENTS	Plant Height (cm)	Number of Productive Tillers	Root Length (cm)	Spikelet Fertility (%)
Factor A (Water Management Techniques)				
A_1 – Continuous Flooding	107.65	11.09	17.96	87.37
A_2 – Rainfed	103.63	11.58	18.98	90.58
A_3 – Alternate Wetting and Drying	102.58	11.79	19.36	90.62
ANOVA Result	ns	ns	ns	ns
Factor B (Nutrient Management Techniques)				
B_1 – Organic Fertilizer (100%)	101.17	11.32	19.16	90.09
B_2 – Combine Organic and Inorganic (50% O + 50% NPK-RR)	105.73	11.77	19.39	89.16
B_3 – Inorganic Fertilizer Application (RR)	106.96	11.37	17.75	89.31
ANOVA Result	ns	ns	ns	ns
Factor A x Factor B				
A_1B_1	99.92	10.53	17.97	86.35
A_1B_2	110.02	11.40	18.33	86.06
A_1B_3	113.02	11.33	17.56	89.70
A_2B_1	103.33	10.97	19.01	90.15
A_2B_2	103.55	11.97	19.82	90.36
A_2B_3	104.02	11.80	18.11	91.23
A_3B_1	100.77	12.47	20.51	93.77
A_3B_2	103.63	11.93	20.01	91.06
A_3B_3	103.85	10.97	17.57	87.01
ANOVA Result	ns	ns	ns	ns
C.V. (%)	5.42	7.82	9.27	4.22

ns- not significant

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Table 2. Yield per Hectare at Different Water and Nutrient Management Techniques.

TREATMENTS	Yield per Hectare (kg)
Factor A (Water Management Techniques)	
A_1 – Continuous Flooding	7085.50^b
A_2 – Rainfed	7508.68^b
A_3 – Alternate Wetting and Drying	8658.86^a
ANOVA Result	**
Factor B (Nutrient Management Techniques)	
B_1 – Organic Fertilizer (100%)	7931.86
B_2 – Combine Organic and Inorganic (50% O + 50% NPK-RR)	7996.96
B_3 – Inorganic Fertilizer Application (RR)	7324.22
ANOVA Result	ns
Factor A x Factor B	
A_1B_1	6966.14
A_1B_2	7291.67
A_1B_3	6998.70
A_2B_1	8398.44
A_2B_2	7096.36
A_2B_3	7031.25
A_3B_1	8430.99
A_3B_2	9602.87
A_3B_3	7942.71
ANOVA Result	ns
C.V. (%)	14.42

Note: Means with common letters are not significantly different with each other.
*** - significant at 1% level*
ns- not significant

Table 3. Nutrient Use Efficiency at Different Water and Nutrient Management Techniques.

TREATMENTS	Nitrogen Use Efficiency (Kg/N Applied)	Phosphorus Use Efficiency (Kg/P Applied)	Potassium Use Efficiency (Kg/K Applied)
Factor A (Water Management Techniques)			
A_1 – Continuous Flooding	176.63	383. 45	124.52^b
A_2 – Rainfed	200.91	428.01	132.40^b
A_3 – Alternate Wetting and Drying	216.03	494.73	152.33^a
ANOVA Result	ns	ns	**
Factor B (Nutrient Management Techniques)			
B_1 – Organic Fertilizer (100%)	417.47^a	210.00^c	146.89^a
B_2 – Combine Organic and Inorganic (50% O + 50% NPK-RR)	115.06^b	363.76^b	140.30^{ab}
B_3 – Inorganic Fertilizer Application (RR)	61.04^c	732.42^a	122.07^b
ANOVA Result	**	**	**
Factor A x Factor B			

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A_1B_1	366.64	126.66	129.00
A_1B_2	104.92	323.83	127.92
A_1B_3	58.32	699.87	116.65
A_2B_1	442.02	258.11	155.53
A_2B_2	102.10	322.79	124.50
A_2B_3	58.60	703.13	117.19
A_3B_1	443.73	245.24	156.13
A_3B_2	138.17	444.68	168.47
A_3B_3	66.19	794.27	132.38
ANOVA Result	ns	ns	ns
C.V. (%)	17.43	32.41	14.40

Note: Means with common letters are not significantly different with each other
*** - significant at 1% level*
ns – not significant

Table 4. Water Use Efficiency at Different Water and Nutrient Management Techniques.

TREATMENTS	Water Use Efficiency (Kg/m³ Applied)
Factor A (Water Management Techniques)	
A_1 – Continuous Flooding	1.54^c
A_2 – Rainfed	3.75^a
A_3 – Alternate Wetting and Drying	2.44^b
ANOVA Result	**
Factor B (Nutrient Management Techniques)	
B_1 – Organic Fertilizer (100%)	2.70
B_2 – Combine Organic and Inorganic (50% O + 50% NPK-RR)	2.58
B_3 – Inorganic Fertilizer Application (RR)	2.45
ANOVA Result	ns
Factor A x Factor B	
A_1B_1	1.54
A_1B_2	1.61
A_1B_3	1.47
A_2B_1	4.20
A_2B_2	3.55
A_2B_3	3.52
A_3B_1	2.37
A_3B_2	2.59
A_3B_3	2.37
ANOVA Result	ns
C.V. (%)	13.91

Note: Means with common letters are not significantly different with each other
*** - significant at 1% level*
ns – not significant

Table 5. Cost and Return Analysis of Rice Production (One Hectare) at Different Water and Nutrient Management Techniques

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TREATMENTS	Cost of Production (Php)	Gross Income (Php)	Net Income (Php)	ROI (%)
A_1B_1	53600.92	101,009.18	47408.26	88.45
A_1B_2	65072.92	105,729.22	40656.29	62.48
A_1B_3	73148.62	101,481.15	28332.54	38.73
A_2B_1	54177.74	121,777.38	67599.64	124.77
A_2B_2	63289.71	102,897.08	39607.37	62.58
A_2B_3	71695.81	101,953.13	30257.31	42.20
A_3B_1	55724.94	122,249.36	66524.42	119.38
A_3B_2	67844.15	133,441.47	65597.32	96.69
A_3B_3	74517.43	115,169.30	40651.87	54.55

Conclusion

Based on the study's results, the alternate wetting and drying method of water management is a good approach to increase rice yield. Integrated nutrient management can also increase yield and nutrient use efficiencies along with alternate wetting, drying, and rainfed conditions. Also, organic fertilizer applications can potentially provide a high return on investment. Similarly, alternate wetting and drying has a high potential for higher economic return in rice production.

Recommendations

The study recommends several water and nutrient management techniques. The alternate wetting and drying and integrated nutrient management increased yields and nutrient use efficiency while rainfed conditions increased return on investment. However, further research should explore to obtain more conclusive result. To confirm observed results, future studies should be conducted in long term effects on soil health, different sources of organic fertilizers, diverse agroecological zones, and integration of precision agriculture technology.

REFERENCES

Al-Juthery, H., Alkhlefawi, A., Al-Taey, D., Al-Janabi, H., Al-Jassani, N., Houria, A., & Al-Salama, Y. (2023). Innovative soil, water and plant management promoting sustainable agriculture and environments: A review. *IOP Conference Series: Earth and Environmental Science,* 1259(1), 012014.

Carrijo, D. R., Lundy, M. E., & Linquist, B. A. (2017). Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. *Field Crops Research,* 203, 173–180.

Chu, T., Yang, H., & Wang, Y. (2017). The impact of alternate wetting and drying irrigation on rice yield and water use efficiency: A meta-analysis. *Agricultural Water Management,* 179, 1–12.

De Fraiture, C., Fayrap, A., Unver, O., & Ragab, R. (2014). Integrated water management approaches for sustainable food production. *Irrigation and Drainage*, 63(2), 221–231.

Dong, B., Mao, Z., Cui, Y., Luo, Y., & Li, Y. (2020). Controlled irrigation for paddy rice in China. *Irrigation and Drainage*, 69(1), 61–74.

Duan, J., Liu, H., Zhang, X., Ren, C., Wang, C., Cheng, L., Xu, J., & Gu, B. (2024). Agricultural management practices in China enhance nitrogen sustainability and benefit human health. *Nature Food*, 5, 378–389.

Hashim, I., Sorour, S., Yosouf, S., El-Sayed, S., & Metwally, T. (2023). Impact of organic fertilizer on some chemical properties of soil, nutrient availability and yield of the wheat-rice cropping system. *Egyptian Journal of Agricultural Research,* 101(2), 424–437.

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International Rice Research Institute (IRRI). (2023). *Water-saving technologies for rice.*

Jiao, X., Lyu, Y., Wu, X., Li, H., Cheng, L., Zhang, C., Yuan, L., Jiang, R., Jiang, B., Rengel, Z., Zhang, F., Davies, W. J., & Shen, J. (2016). Grain production versus resource and environmental costs: Towards increasing sustainability of nutrient use in China. *Journal of Experimental Botany*, 67(17), 4935–4949.

Lal, R. (2020). Soil organic matter content and crop yield. Journal of Soil and Water Conservation, 75, 27A–32A.

Lampayan, R. M., Rejesus, R. M., Singleton, G. R., & Bouman, B. A. M. (2015). Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. *Field Crops Research,* 170, 95–108.

Liu, P., Zhang, T., Wang, G., Ju, J., Mao, W., & Zhao, H. (2023). Response of rice grain yield and soil fertility to fertilization management under three rice-based cropping systems in reclaimed soil. *Agronomy,* 13(7), 1840.

Liu, X., Li, M., Guo, P., & Zhang, Z. (2019). Optimization of water and fertilizer coupling system based on rice grain quality. *Agricultural Water Management,* 221, 34–46.

Liu, Z., Cao, S., Sun, Z., Wang, H., Qu, S., Lei, N., et al. (2020). Tillage effects on soil properties and crop yield after land reclamation. *Scientific Reports,* 11, 4611.

Lv, M., Huang, M., Zhao, K., Gu, X., Li, S., Wang, J., & Fu, G. (2023). Effects of partial substitution of organic fertilizer for synthetic N fertilizer on yield and N use efficiencies in a semi-arid winter wheat–summer maize rotation. *Agronomy,* 13(9), 2281.

Maneepitak, S., Ullah, H., Paothong, K., Kachenchartm, B., Datta, A., & Shrestha, R. P. (2019). Effect of water and rice straw management practices on yield and water productivity of irrigated lowland rice in the Central Plain of Thailand. *Agricultural Water Management*, 211, 89–97.

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Sustainability: Four billion people facing severe water scarcity. *Science Advances,* 2, 1–6.

Mueller, N. D., Gerber, J. S., Johnston, M., Ray, D. K., Ramankutty, N., & Foley, J. A. (2012). Closing yield gaps through nutrient and water management. *Nature,* 490(7419), 254–257.

Nkebiwe, P. M., Weinmann, M., Bar-Tal, A., & Müller, T. (2016). Fertilizer placement to improve crop nutrient acquisition and yield: A review and meta-analysis. *Field Crops Research,* 196, 389–401.

Palansooriya, K. N., Dissanayake, P. D., Igalavithana, A. D., Tang, R., Cai, Y., & Chang, S. X. (2023). Converting food waste into soil amendments for improving soil sustainability and crop productivity: A review. *Science of the Total Environment,* 881, 163311.

Pandey, C., & Shukla, S. (2006). Effects of composted yard waste on water movement in sandy soil. *Compost Science & Utilization,* 14(3), 252–259.

Putri, R., Suwardi, S., Iskandar, I., Sumawinata, B., & Fawzi, N. (2024). Effects of land and water management on bulk density of peat soils in coconut plantations. *IOP Conference Series: Earth and Environmental Science,* 1421(1), 012007.

Sardans, J., & Peñuelas, J. (2021). Potassium control of plant functions: Ecological and agricultural implications. *Plants,* 10(2), 419.

Soliman, E., Azam, R., Hammad, S., Mosa, A., & Mansour, M. (2024). Impacts of alternate wetting and drying technology on water use and soil nitrogen transformations for sustainable rice production: A review. *Journal of Soil Sciences and Agricultural Engineering,* 0(0), 151–163.

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P - ISSN 2984-7842
E - ISSN 1908-3181

Tuong, T. P., & Bouman, B. A. M. (2003). Rice production in water scarce environments. In J. W. Kijne, R. Barker, & D. Molden (Eds.), *Water productivity in agriculture: Limits and opportunities for improvement* (pp. 53–67). CABI Publishing.

Ye, Y., Zhang, H., & Wang, J. (2013). Water-saving irrigation practices for rice yield information and nitrogen use efficiency under sub-tropical monsoon climate. *Water Science and Technology,* 67(7), 1480–1486.

Zhang, H., Xue, Y., Wang, Z., Yang, J., & Zhang, J. (2009). An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. *Crop Science,* 49(6), 2246–2260.

Zhang, H., Wang, J., & Ye, Y. (2020). Maximizing water use efficiency in rice farming: A comprehensive review of innovative irrigation management technologies. *Water,* 15(10), 1802.

Zhou, Q., Ju, C. X., Wang, Z. Q., Zhang, H., Liu, L. J., Yang, J. C., & Zhang, J. H. (2017). Grain yield and water use efficiency of super rice under soil water deficit and alternate wetting and drying irrigation. *Journal of Integrative Agriculture,* 16(5), 1028–1043.