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Productivity of hybrid rice (Mestizo 27) under different water and nutrient management systems

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ABSTRACT

This study examines the productivity of hybrid rice under different water and nutrient management systems. At Isabela State University, Cabagan, Isabela, we conducted a field experiment to determine the productivity of hybrid rice production under different water and nutrient management strategies. It was laid out in a split-plot design with four replications. Water management schemes as main plot consisted of alternate wetting and drying at -15 cm (A1), alternate wetting and drying at -20 cm (A2), field capacity (A3), and continuous flooding (A4), while nutrient management strategies as subplot consisted of recommended rate (B1), leaf color chart (B2), critical growth periods (B3), and rice crop management (B4). The Mestizo 27 subjected to nutrient management through the leaf color chart (B2) gained highest on the number of productive tillers, filled grains, biomass weight, and grain yield. Similarly, the interaction effect of field capacity and leaf color chart (A3xB2) resulted in numerous productive tillers, which increased the yield, net income, and return on investment. Moreover, water management through the field capacity (A3), continuous flooding (A4), and AWD-15 (A1) in combination with leaf color charts (B2) produced highest grain yield among treatments. Hence, the use of leaf color chart in combination with different water management schemes was seen as effective in increasing the yield of Mestizo 27 even beyond safe AWD-15.

Contribution/ Originality: This study investigates the productivity of hybrid rice as influenced by different water management strategies through alternate wetting and drying, field capacity, and continuous flooding, as well as nutrient management strategies through leaf color charts, critical growth periods, recommended rates, and rice crop management. This study uses split plot design with four replications.

1. INTRODUCTION

Tackling hunger is one of the greatest challenges of our time. It is nearly impossible to draw solutions to the unprecedented effect of climate variability, but rather to mitigate and adapt to this uncertainty.

The demand for food is anticipated to increase by more than 50% as the world's population is projected to reach more than 9 billion by 2050 [1]. The demand for water has greatly increased as a result of the population's rapid growth. Agriculture accounts for 90% of the world's consumptive water consumption, consuming 70% of all freshwater [2]. The sustainability of food production and the ecosystem services provided by rice fields are at risk due to impending water scarcity; as a result, it is necessary to develop and spread water management techniques that can assist farmers in coping with water scarcity in irrigated areas [3].

About two-thirds of the world's population depends on rice (Oryza stiva L.), which is a major staple food and the agricultural sector's largest water user [4]. Irrigated lowland rice continues to be the primary source of food supply, and this dependence on rice affects food security globally [5].

Many water-saving strategies and procedures have been developed for rice farmers to reduce water demand and maintain an acceptable yield because agricultural water productivity directly impacts crop output. The most widely used method for conserving water is alternate wetting and drying (AWD). One of the techniques under AWD is the safe AWD-15, which re-irrigates fields to a ponded level of 5 cm above the soil surface after allowing water to fall as low as 15 cm below the soil surface.

The two main factors limiting agricultural productivity are insufficient water and nutrients [6]. The strong relationship between water and crop nutrients can be explained by the multiple impacts of water on the movement of nutrients from unavailable to available forms, the distribution of water to plant roots, and loss mechanisms in the diverse impacts of water on the transfer of nutrients from unavailable to available forms, the transport of nutrients to plant roots, and loss mechanisms in [7].

Efficient water management can enhance nitrogen availability and nutrient transformation in the soil or from fertilizers [6]. On the other hand, fertilizer management involves allocating fertilizer according to the soil, climate, and crop management conditions specific to a single field, taking into account factors like rate source, timing, and location. In order to minimize off-site fertilizer transfer that could harm the environment and to maximize crop yields, quality, and economic returns, the best nutrient management systems should be created [8].

Hybrid rice technology can increase rice yields [9]. Super hybrid rice cultivars have better physical characteristics than inbred rice cultivars, such as higher biomass production, lower panicle position, and larger panicle size [10]. Hybrid rice also has a stronger stem and more vigorous roots [11], as well as a longer root system [12]. Deeper-rooted crops boost resource uptake and efficiency significantly [13]. Several studies have shown that the most critical variable for optimum subsurface water consumption to avoid drought is rooting depth [14].

To pursue the fastest and most practical route to increasing yield, apply and extend existing agricultural technologies. To exploit the yield benefits of hybrid rice, technologies for proper water and nutrient management should be developed. Thus, the objective of this study is to determine the productivity of hybrid rice under different water and nutrient management strategies.

2. MATERIALS AND METHODS

The experiment was conducted from February 23, 2018 to June 05, 2018 at the College of Agricultural Sciences and Technology (CAST) Laboratory Farm, Isabela State University, Cabagan, Isabela. Climatic data during the conduct of study was monitored by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) stationed in the City of Tuguegarao. The area is relatively flat and solely planted with rice twice a year (in the wet and dry seasons). Soil sampling was conducted following the standard procedure for collection. The soil samples were analyzed at the Bureau of Soils, Water and Management (BSWM).

The rice seed used in the study was Mestizo 27, named by the National Seed Industry Council (NSIC) as NSIC Rc234H. It is a high-yielding variety with an average yield of 6.5 t ha-1 and could reach a maximum yield of 9.8 t ha-1. At 115 days old, it matures and has an average height of 119cm. It is widely adaptable during dry season.

The experiment was laid out in a split-plot design with four replications. The water management schemes serve as the main plot, consisting of Alternate Wetting and Drying -15 cm (A1), Alternate Wetting and Drying -20 cm (A2), Field Capacity (A3), and Continous Flooding (A4), while the nutrient management strategies serve as subplots consisting of Recommended Rate (B1), Leaf Color Chart (B2), Critical Growth Periods (B3), and Rice Crop Manager (B4).

The area was divided into four equal blocks, replicated two meters apart. We constructed dikes and canals around the blocks for better drainage. It was also further subdivided into sixteen plots with a dimension of 4.5m x 5.0m. The surrounding bunds of these plots are lined with plastic sheet dug at 30 cm depth to avoid seepage or lateral movement of water and nutrients.

AWD treatments were installed with field water tubes known as "Pani Pipe," which is made up of polyvinyl chloride (PVC) pipe. AWD-15 pani pipe has a dimension of 15 cm in diameter and 30 cm in length while AWD-20 has a 15 cm in diameter and 40 cm in length. The tubes were perforated with many holes on all sides, so that water could move freely inside the pipes. The pani pipes were buried into the soil up to 15 cm for AWD-15 and 20 cm below the soil surface. The tubes were placed in all the treatments in a readily accessible part of the field close to a bund, so monitoring the ponded water depth is easy. For AWD-15 and AWD-20, when water levels drop to 15 cm and 20 cm below the soil surface, irrigation is supplemented until 5 cm of water level above the soil surface is attained.

We use the moisture meter to monitor the field capacity (FC). Irrigation of 5 cm above the soil surface was immediately done when moisture reached below 50% of the field capacity. In continuous flooding (CF) treatments, the field was flooded following the International Rice Research Institute (IRRI) technology as follows: (a) 2 cm depth after transplanting up to tillering stage, (b) 5 cm depth during the booting stage; and (c) 3 cm depth during milking stage to maturity.

Subplots of nutrient management treatments include rate, source, timing, and place of nutrient application. In the Recommended Rate (RR) plots, rate and timing of application were based on the soil analysis results. Soil was analyzed at 140-30-0 kg-ha with soil pH of 5.2 and organic matter at 1.34% N. A similar rate was being used in plots using leaf color chart (LCC) during basal application.

The LCC reading was started 14 days after transplanting (DAT) and was done weekly until the first flowering. If more than 5 out of ten leaves show readings below 4, 30 kg.ha-1 of urea was applied.

The critical growth stage of a plant varies as it is affected by abiotic stresses. Rate of nutrient application in plots under critical growth period (CGP) was based on the soil analysis recommendation, while the timing of application was based on critical growth periods of the crop.

The rate and timing of nutrient application in plots using rice crop manager (RCM) were based on the recommendation of RCM version 2.0. Using the software application at https://phapps.irri.org/ph/rcmfm/, guide questions were provided wherein target yield together with the previous cropping management practices were given as basis for the app recommendations of 89.1-22.4-22.4 kg-ha.

The analysis of variance (ANOVA) was performed to analyze the main effect of the two factors (water management and nutrient management) and their interactions using the statistical software Statistix 10 following split plot design. When the interaction is significant (present), the combination treatment means are compared using the Tukey's honestly significant difference (HSD) at 5% and 1% levels of significance. The Coefficient of Variation (CV) was also computed to measure the absolute precision and reliability of the experiment.

Lastly, the data were analyzed for profitability through a simple cost-return analysis with cost-benefit ratio.

3. RESULT AND DISCUSSION

3.1. Number of Days at 50 %Flowering

Figure 1 displays the number of days at 50% flowering as influenced by water and nutrient management. Fifty percent of flowering was affected by water management at 68 days after transplanting (DAT) in field capacity and continuous flooding treatments (FC and CF), and 73 DAT in alternate wetting and drying -15 and alternate wetting and drying -20 (AWD-15 and AWD-20). On the other hand, in nutrient management treatments early flowering was observed in leaf color chart (LCC), and delayed flowering was observed in critical growth period (CGP) and recommended rate (RR) treatments. Figure 2 also illustrates the interaction effect of water and nutrient management on 50% flowering. 50% flowering was observed in CF x LCC and FC x LCC at 65 DAT, and the longest duration was recorded by AWD treatments ranging from 73-75 DAT.

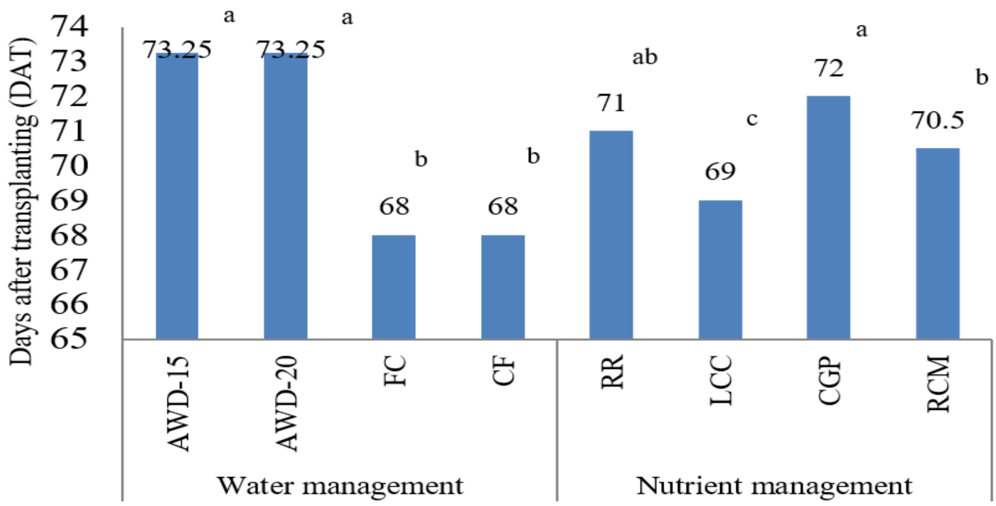

Figure 1. Number of days at 50% flowering of Mestizo 27 as affected by water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly Significant Difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b and c.
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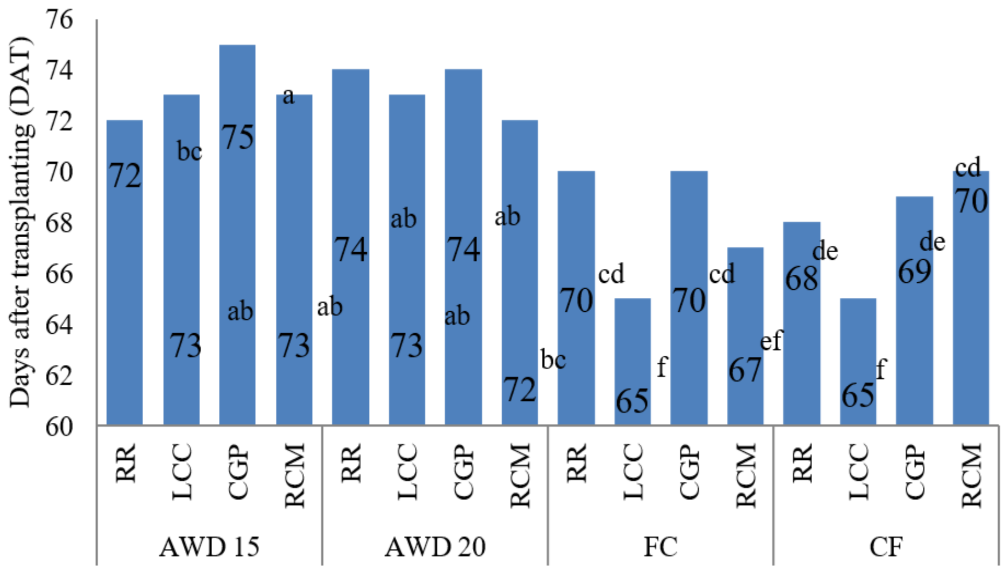

Figure 2. Number of days at 50% flowering of Mestizo 27 as affected by the interaction of water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly Significant Difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b, c, d, e and f.
b present: b is significantly different with a, c, d, e and f.
c present: c is significantly different with a, b, d, e and f.
d present: d is significantly different with a, b, c, e and f.
e present: e is significantly different with a, b, c, d and f.
f present: f is significantly different with a, b, c, d, and e.

3.2. Number of Days to Maturity

The mean number of days of maturity of Mestizo 27 as affected by water and nutrient management is reflected in Figure 3. Similar data trends with the number of days to flower in water management were observed. FC and CF treatments matured at 98 DAT, while AWD treatments matured at 103 DAT. Nutrient management also affected the maturity days, whereas LCC matured at 99 DAT, and the longest was CGP treatments at 101 DAT. Meanwhile, in Figure 4, the interaction effect of water management through FC and CF with all nutrient management strategies matured at a range of 95.5-100 DAT, whereas AWD treatments in combination with different nutrient management strategies matured 102-104 DAT.

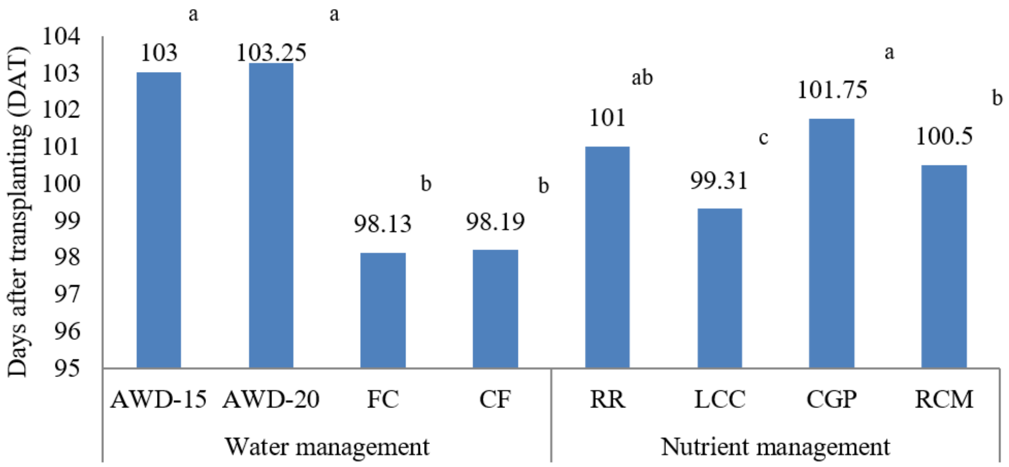

Figure 3. Number of days at maturity of Mestizo 27 as affected by water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly Significant Difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b and c.
b present: b is significantly different with a and c.
c present: c is significantly different with a and b.

Figure 4. Number of days at maturity of Mestizo 27 as affected by the interaction of water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly Significant Difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b, c and d.
b present: b is significantly different with a, c and d.
c present: c is significantly different with a, b and d.
d present: d is significantly different with a, b and c.

3.3. Plant Height at 30, 45 and 60 Days after Transplanting (cm)

Figure 5 shows how water and nutrient management affect Mestizo 27's plant height. Analysis of variance (AOV) reveals that there is no significant difference among treatments in plant height at 30, 45, and 60 days after transplanting. This shows that water and nutrients were sufficiently received by the different treatments at different growth stages; therefore, heights were not affected. Plant heights increased regularly as plant growth progressed [15].

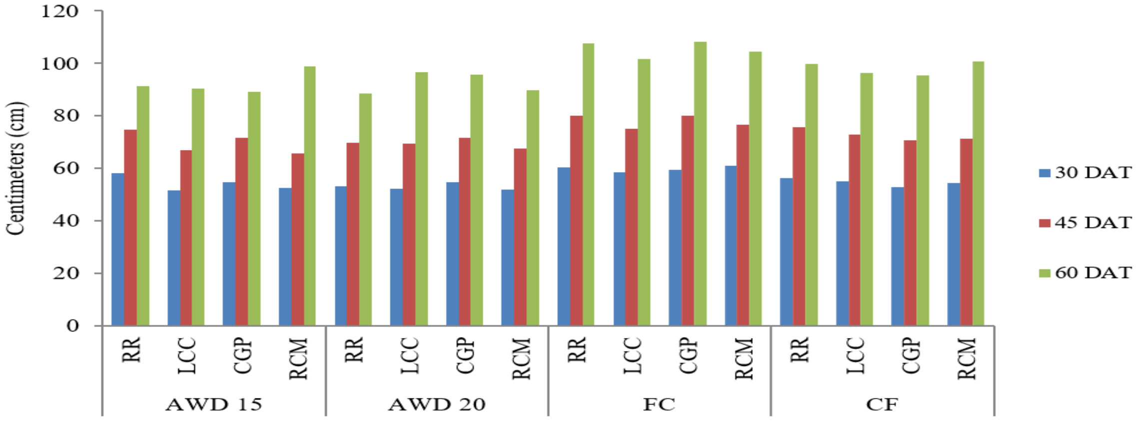

Figure 5. Plant height of Mestizo 27 at 30, 45 and 60 DAT as affected by the interaction of water and nutrient management.

3.4. Number of Productive Tillers per Hill

As shown in Figure 6, productive tillers were significantly affected by nutrient management. The use of LCC produced 15.31 productive tillers, while CGP, RR, and RCM produced productive tillers ranging from 12.98-13.18. The use of leaf color chart (LCC) increases the amount of nitrogen fertilizer application, thus enhancing the production of tillers. The application of nitrogen (N) fertilizer is the most common and effective way to enhance the tiller population [16]. Similarly, as shown in Figure 7, productive tillers were also significantly affected by the interaction of water and nutrient management. FCxLCC and CFxLCC gained highest number of productive tillers per hill at 16.5 and 16.3, respectively, while AWD-20xCGP got the least number at 10.8. This shows that, with sufficient water and nutrients, plants developed numerous productive tillers. Hybrid rice has robust roots, and given enough water and nutrients in the soil, it produces more tiller-forming panicles [17].

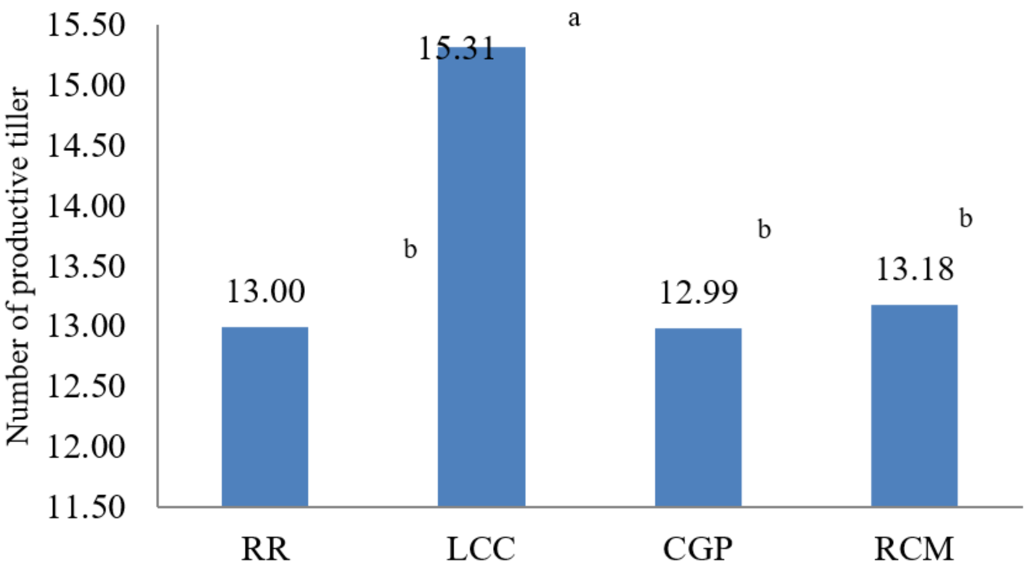

Figure 6. Number of productive tillers of Mestizo 27 as affected by nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

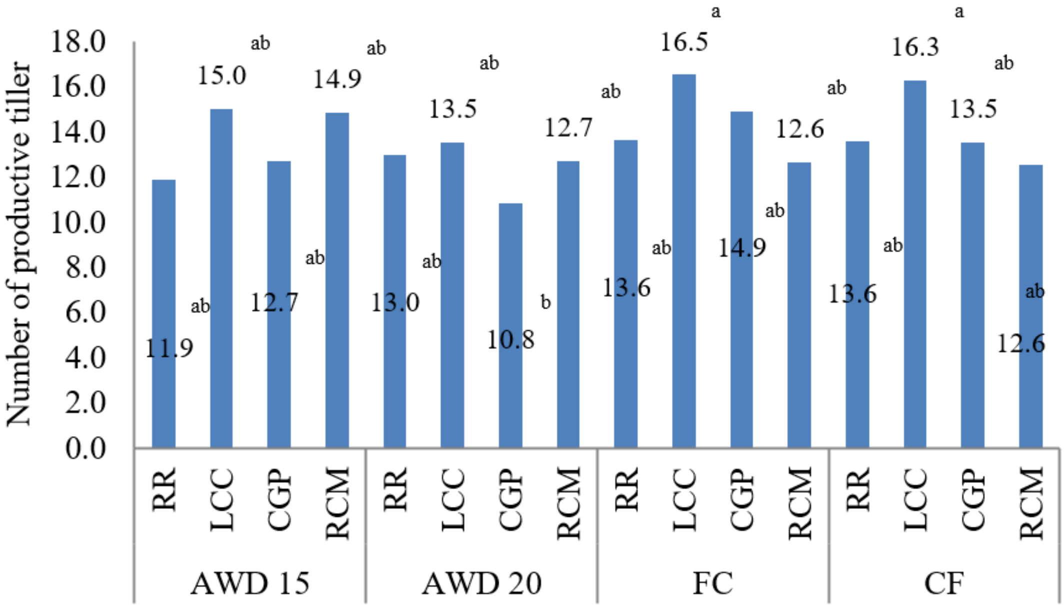

Figure 7. Number of productive tillers of Mestizo 27 as affected by the interaction of water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level (p<0.05).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.5. Number of Unproductive Tillers per Hill

Figure 8 presents the number of unproductive tillers per hill as affected by water management strategies. Numerous unproductive tillers were significantly higher in CF with a mean of 4.83 and statistically the same with AWD-20 and AWD-15, while FC recorded the least number of 3.24. The effect of shading on continuously flooded soil (CF) and the leaching of applied nutrients induced the occurrence of unproductive tillers. Reduced photosynthetic activity, as in the case of AWD impedes, the translocation of assimilates, thereby causing the production of unproductive tillers. Environmental conditions and varietal traits influence the growth and development of tillers [18]. However, the number of unproductive tillers per hill was not affected by nutrient management and its interaction with water management.

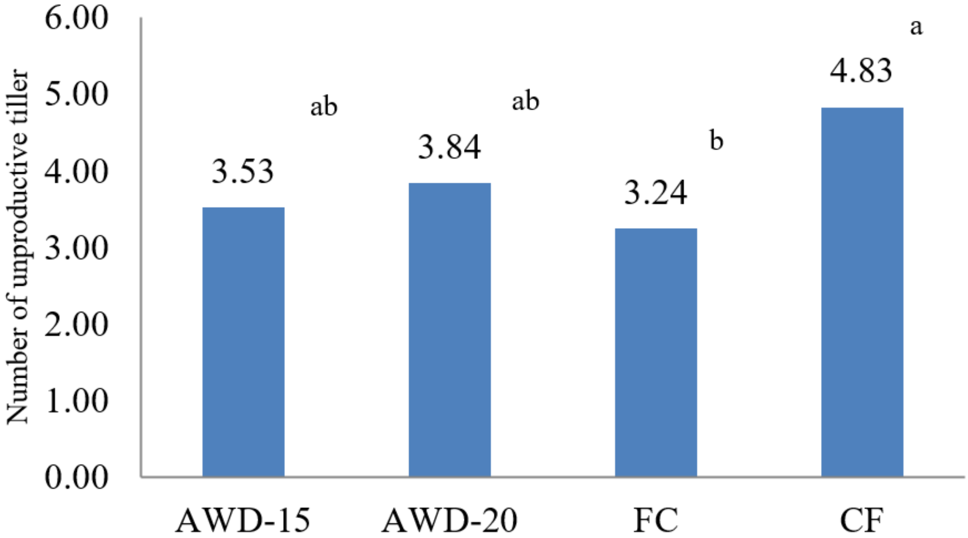

Figure 8. Number of unproductive tillers of Mestizo 27 as affected by nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level (p<0.05).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.6. Root Length (cm)

Figure 9 shows that the length of roots ranges from 26.31 cm to 28.9 cm. Numerically, AWD treatments recorded the longest, while FC and CF recorded the shortest. AOV reveals that there is no significant difference among the different treatments. Under mild water deficits, as in the case of AWD treatments, the root growth usually maintains while shoot growth is inhibited. This is because changes like re-establishing the water potential gradient through osmotic modification and making it easier for cell walls to break down and let roots keep growing even when there isn't enough water [19].

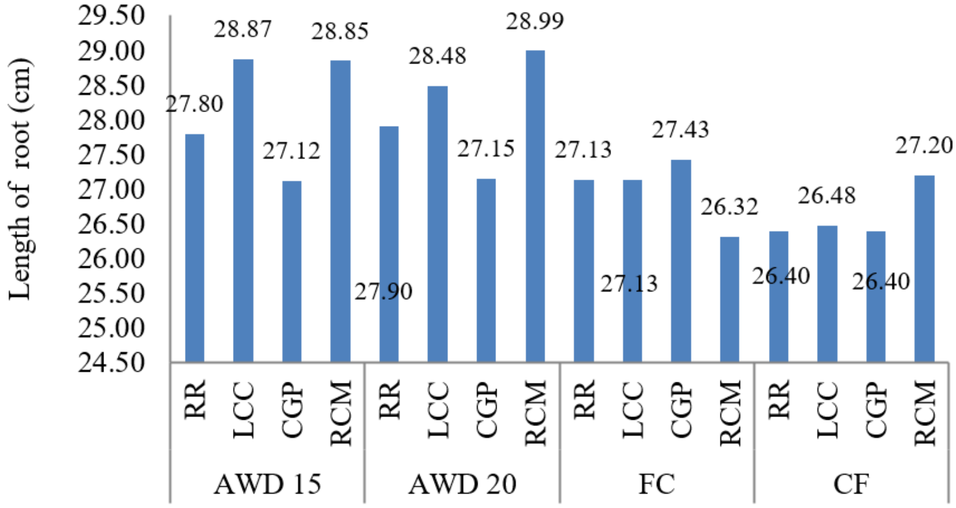

Figure 9. Length of roots of Mestizo 27 as affected by the interaction of nutrient and water management.

3.7. Length of Panicle (cm)

AOV revealed that the length of panicles was not affected by water management and its interaction with nutrient management; however, nutrient management as single factor significantly affected the length of panicles, as shown in Figure 10. LCC produced longest panicle at 28.71 was statistically the same as RCM and CGP, with means of 27.92 and 27.21, respectively. RR produced the shortest panicle, measuring 26.98 cm. More balanced nutrient availability could explain the increase in panicle duration [20].

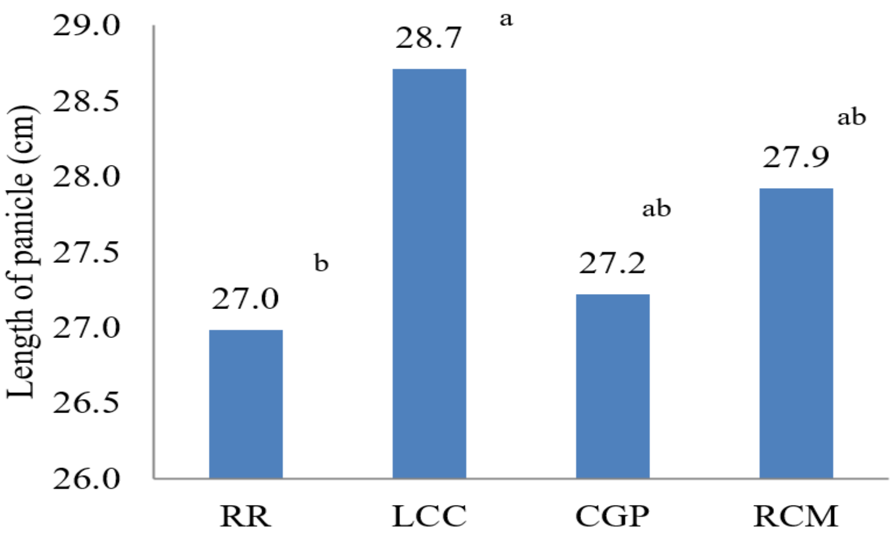

Figure 10. Length of panicles of Mestizo 27 as affected by nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly Significant Difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.8. Number of Filled Grains per Panicle

The graphical presentation in Figure 11 showed that nutrient management significantly affected the number of filled grains. Application of fertilizer at the right time, as in the case of LCC, which obtained the highest mean number of filled grains at 149.53 and was statistically at par with RCM at 138.07, followed by RR at 131.30, and the least was recorded by CGP at 128.87. We can attribute the results to the high rates of fertilizers applied during the vegetative stage, leading to a high panicle density [21]. On the other hand, AOV revealed that water management and its interaction with nutrient management do not affect the number of filled grains.

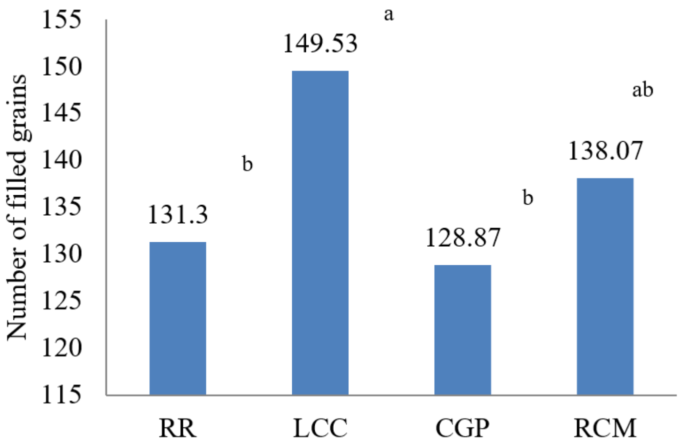

Figure 11. Number of filled grains of Mestizo 27 as affected by nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.9. Number of Unfilled Grains per Panicle

Water and nutrient management also had an impact on unfilled grains, as shown in Figure 12. AWD-20 produces the highest mean number of unfilled grains at 59.42 and is statistically on par with FC at 48.76. While AWD-15 and CF, with means of 45.46 and 42.43, were statistically the same with FC. Spikelet sterility or unfilled grains recorded at AWD-20 could be due to high temperatures during the flowering stage and also to a water deficit. This observation is reinforced by De Datta and Buresh [22] who found severe desiccation of spikelets and anthers at low water potentials. On the other hand, highly significant difference was observed on the effect of nutrient management on unfilled grains. LCC obtained the fewest mean number of unfilled grains at 31.18, while RR, RCM, and CGP got highest ranging from 50.52-57.78.

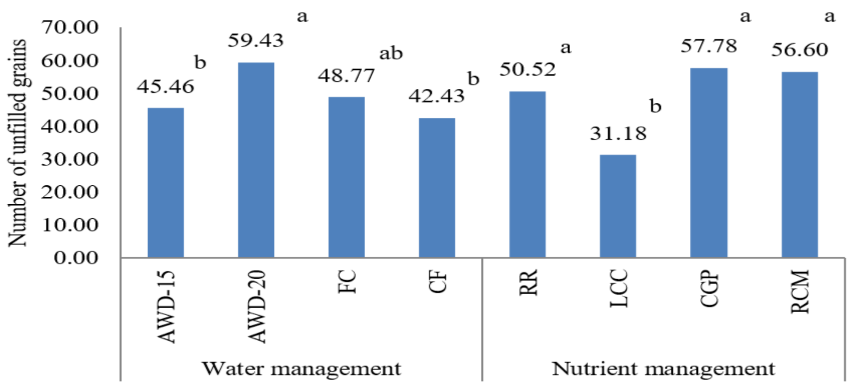

Figure 12. Number of unfilled grains of Mestizo 27 as affected by water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
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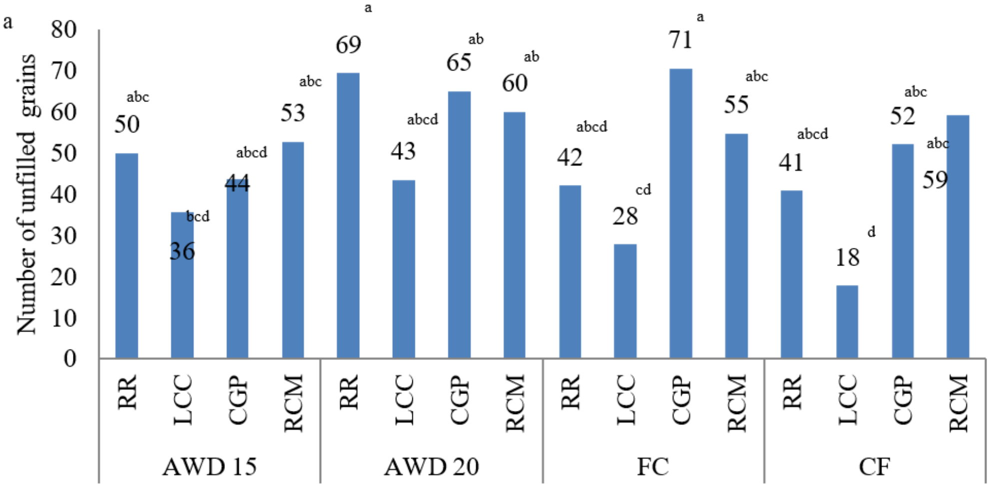

Figure 13. Number of unfilled grains of Mestizo 27 as affected by the interaction of water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b, c and d.
b present: b is significantly different with a, c and d.
c present: c is significantly different with a, b and d.
d present: d is significantly different with a, b and c.

Meanwhile, highly significant differences were observed in the interaction of water and nutrient management on the number of unfilled grains, as shown in Figure 13. Treatments under AWD-20, and AWD-15 with RCM, CGP and RR gained numerous unfilled grains with means ranging from 40.7 to 70.5 while water management treatments with LCC gained the least unfilled grains ranging from 17.75-43.5. This finding is consistent with Venkatesan, et al. [23] report, which indicated that the amount of chaffy grains per panicle was higher in stressed crops.

3.10. Biomass Yield (g)

As presented in Figure 14, nutrient management through LCC produced the heaviest weight at 390.44 g, followed by RCM, RR, and CGP with means ranging from 337.62-342.71 g. The use of LCC as an indicator of N status is effective in determining N deficiency. RCM, RR, and CGP, may suffer from a nitrogen deficiency because photosynthetic activity decreases at low N levels [24].

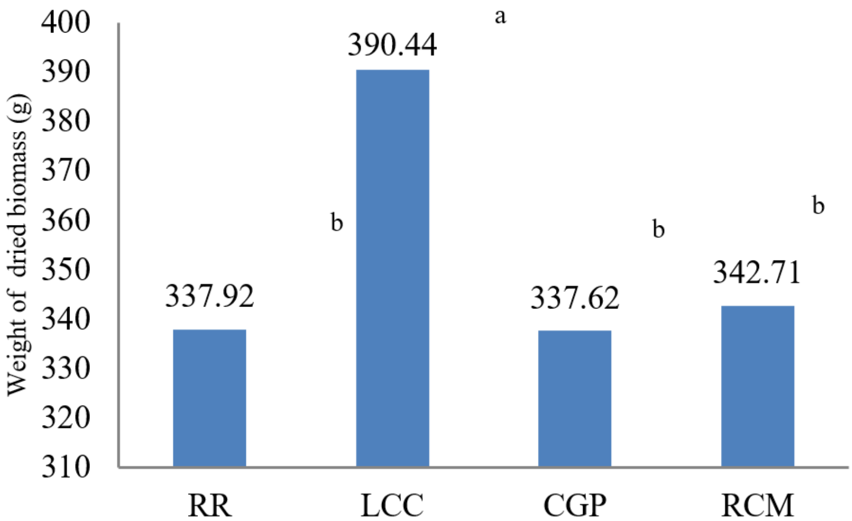

Figure 14. Weight of dried biomass of Mestizo 27 as affected by nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

Moreover, the biomass yield was not affected by water management but by its interaction with nutrient management. Figure 15 showed that the heaviest among the treatments was gained by FCxLCC at 423.25 g was significantly different from AWD-20xCGP which was the lightest at 281.99 g. A study by Mahmood, et al. [25] reported that the high dry mass of the grains, leaves, and stems in the anaerobic-flooded regime, as in the case of FC, was attributed to the sufficient amount of water and nutrients in the root zone for rice.

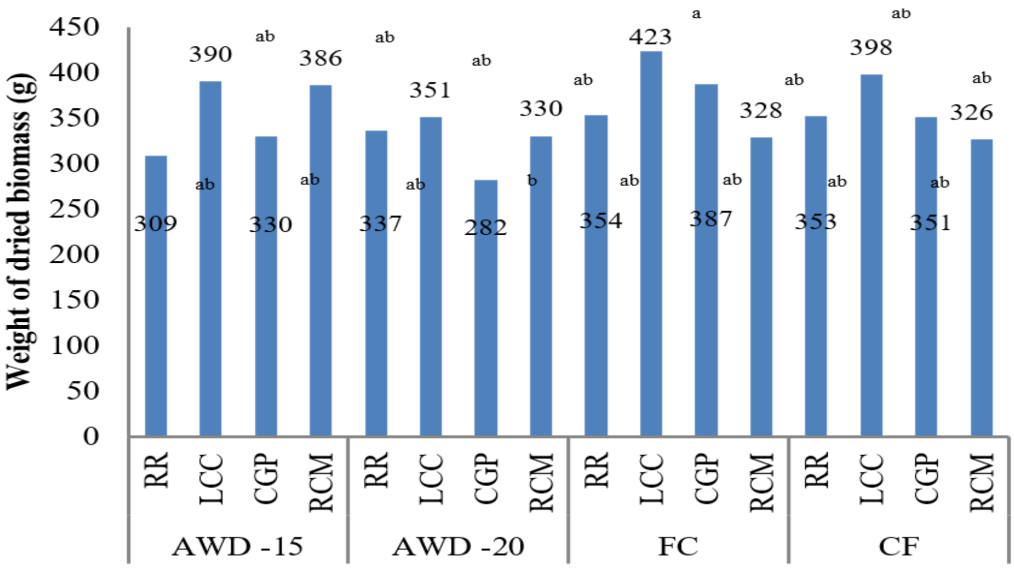

Figure 15. Weight of dried biomass of Mestizo 27 as affected by the interaction of water and nutrient management system.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.11. Weight of 1000 Grains

AOV showed that the weight of 1000 grains was not affected by water and nutrient management and their interaction as shown in Figure 16. Numerically, FCxLCC gained the heaviest at 23 g while the lightest was recorded by AWD-20xRR with mean weight of 20.25 g.

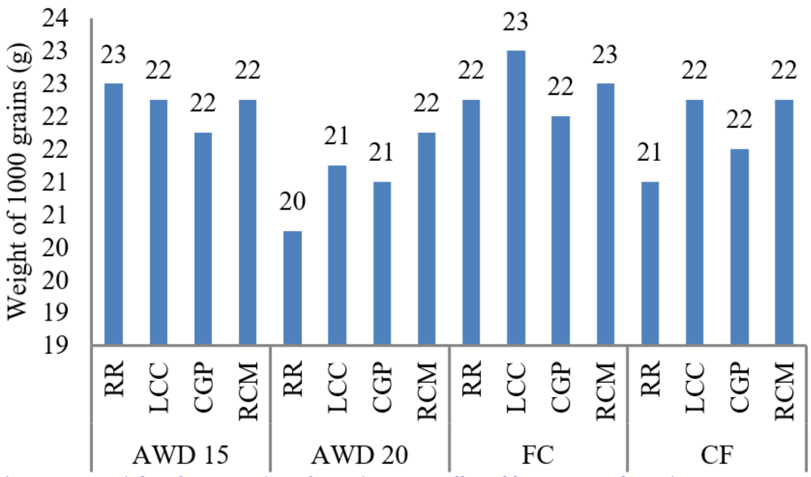

Figure 16. Weight of 1000 grains of Mestizo 27 as affected by water and nutrient management.

3.12. Computed Yield

Figure 17 presents the computed yield in tons/ha of Mestizo 27 as affected by water and nutrient management as single factor. A significant difference was observed in water management strategies. Result of the AOV reveals that FC yielded highest at 9.1 t ha-1 and was on par with CF and AWD-15, while significantly different with

AWD-20 at 6.63 t ha-1. Yield in AWD0-20 compared to average potential yield of the variety, which is 6.5 t/ha is quite high. This could be attributed to the increased assimilate allocation to the roots because of osmotic pressure and hydrotropism caused by alternately wetting and drying the soil [26]. On the other hand, the effect of nutrient management reveals that the use of LCC gained the highest yield at 10.29t ha-1 and was statistically different from RCM, RR, and CGP, with mean yields of 7.82t ha-1, 7.06t ha-1 and 6.99t ha-1, respectively. These findings aligned with prior research indicating that fertilization impacted yield components, leading to typically higher crop yields correlating with soil fertility levels [27].

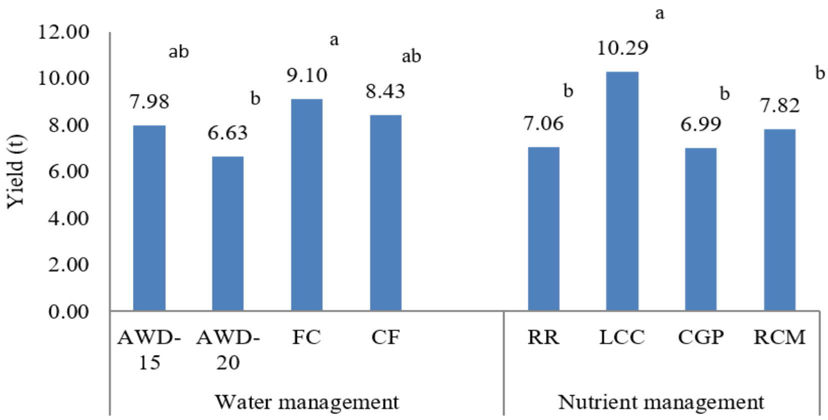

Figure 17. Grain yield of Mestizo 27 as affected by water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

Similarly, highly significant difference was observed in the interaction of water and nutrient management, as presented in Figure 18, wherein FC x LCC got the highest yield at 11.94t ha-1 and statistically the same with other treatments except for AWD-20 x CGP, which gained the lowest yield at 5.19t ha-1. It only takes creating the ideal drought condition, according to Tardieu [28] for any crop to bestow drought tolerance on a crop. Modern rice cultivars have been adapted to semi-aquatic settings with just intermittent flooding, according to Ye, et al. [29] who relied on a lot of research in their argument. Furthermore, based on recently conducted studies, According to Yang, et al. [30] and Bouman, et al. [3] AWD, when used within specified parameters, can boost yield by eliminating redundant vegetative development, increasing hormone levels, strengthening root growth and canopy structure, and enhancing the transfer of carbon from vegetative tissues to grains.

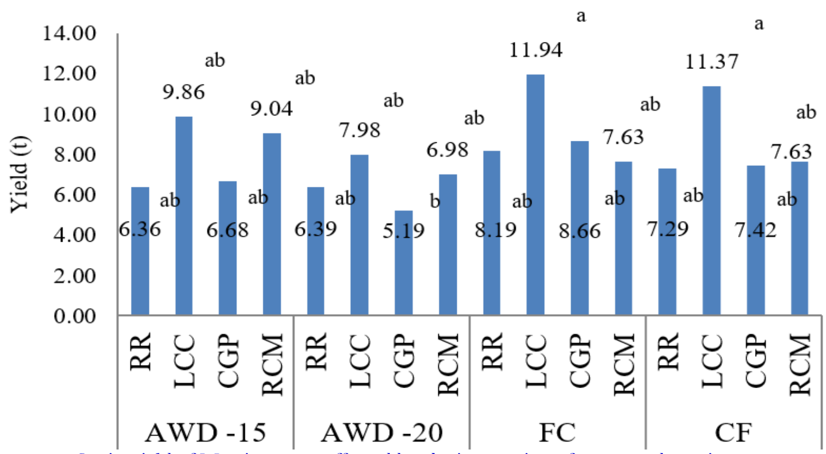

Figure 18. Grain yield of Mestizo 27 as affected by the interaction of water and nutrient management.

Note: Means not sharing letter in common differ significantly by Tukey's HSD (Honestly significant difference) at 5% significance level ($p<0.05$).
a present: a is significantly different with b.
b present: b is significantly different with a.

3.13. Cost and Return Analysis

As shown in Table 1, FC x LCC gained highest net income and benefit cost ratio of 107%, while AWD-20xCGP gained the least net income and a return on investment of 25%. This shows that adequate moisture and nutrients in the soil produce a high yield consequently a high profit, while the use of AWD during an expected drought is promising for rice production as it secures net income.

Table 1. Cost and return analysis.

Treatments	Yield/ ha	Gross income	Total expenses	Net income	Return on investment
AWD-15 x RR	6.36	108065.77	73345	34720.77	47%
AWD-15 x LCC	9.85	167531.81	85013	82518.81	97%
AWD-15 x CGP	6.68	113547.80	72345	41202.8	57%
AWD-15 x RCM	9.04	153619.26	93345	60274.27	65%
AWD-20 x RR	6.39	108667.99	70327	38341	55%
AWD-20 x LCC	7.98	135645.55	83015	52630.55	63%
AWD-20 x CGP	5.19	88147.90	70327	17820.9	25%
AWD-20 x RCM	6.98	118683.56	70327	48356.57	69%
FC x RR	8.19	139208.88	83447	55761.89	67%
FC x LCC	11.94	203020.16	87087	115933.2	133%
FC x CGP	8.66	147239.89	93345	53894.89	58%
FC x RCM	7.63	129639.96	93345	36294.96	39%
CF x RR	7.29	123893.74	89107	34786.75	39%
CF x LCC	11.37	193253.66	93345	99908.66	107%
CF x CGP	7.42	126152.44	87645	38507.45	44%
CF x RCM	7.63	129656.79	89,000	40656.79	46%

4. CONCLUSION

Based on the result of the study the following conclusions were drawn; (a)water management thru FC and nutrient recommendation thru LCC produced the best result effect on all the growth and yield parameters; (b) plant height, root length and weight of 1000 grains are not affected by nutrient management strategies but with water management; (c) sufficient moisture thru FC, CF and safe AWD-15 produced more productive tillers, heavy biomass weight and grain yield; (d) water is very crucial in all growth and yield parameters but the effect of mild water deficit on AWD-20 does not compromise yield reduction beyond average yield but comparable with safe AWD-15; (e)the combination of all water management schemes with leaf color chart is seen to be effective in maintaining and increasing the yield of hybrid rice variety even beyond safe AWD-15; (f) the use of field water tube or pani pipe is very effective in monitoring water depth; and (g) cost benefit is higher in water management treatments with leaf color chart.

5. RECOMMENDATIONS

The study's findings lead to the following recommendations:

1. Use hybrid rice varieties and AWD during an expected drought as a mitigation strategy to sustain yield.
2. Install water tube or pani pipe in the rice field to monitor water level and avoid excessive water loss.
3. Use leaf color chart as nutrient indicator to avoid excessive and insufficient nitrogen supply.
4. A follow-up study should also be conducted to validate the result and to include other growth parameters and water cost calculations.

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