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Irrigation Deficit for Ciherang Rice Variety as a Benchmark for Developing Upland Rice Cultivation Systems

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ABSTRACT

This study aims to evaluate the agronomic response of Ciherang rice plants during the vegetative and generative phases under deficit irigation conditions, as a benchmark for cultivation in dry land. This study used a factorial Completely Randomized Design with two factors. First, the level of water efficiency consisting of three levels, namely 300 ml, 600 ml, and 900 ml; second, the ratio of cattle manure and urea fertilizer also consisting of three levels, namely 80:20, 50:50, and 20:80. The observed variables include vegetative phase parameters, such as plant height, number of tillers, and dry weight of biomass, as well as generative phase parameters, such as percentage of filled grains and weight of filled grains per clump. The results showed that there was a significant interaction between water efficiency and fertilizer ratio during the generative phase, but no similar interaction was found during the vegetative phase. Furthermore, the combination of 600 ml water treatment with a 50:50 fertilizer ratio produced the highest percentage of filled grains and weight of filled grains. These results indicate that Ciherang rice can grow well under efficient water conditions, making it potentially suitable for cultivation in dry land.

1. INTRODUCTION

Indonesia is the largest rice-producing country in Southeast Asia (Abraham *et al*., 2016) and the third-largest in the world (Haryanto *et al*., 2019). Rice is a staple food source for Indonesia. Rice production is expected to meet the population's rice consumption needs, which are constantly increasing from 27 million tons per year (Mutiara, 2015) to approximately 32.07 million tons per year (Meliawati *et al*., 2023). In other words, based on data from Badan Pangan Nasional (2024), rice consumption has increased from 93.5 kilograms (kg) per capita per year in 2022 to 93.8 kg per capita per year in 2023. This is to offset Indonesia's population growth rate of 1.49% per year.

One factor contributing to increased rice production is the development of dryland rice cultivation. Efforts to improve soil fertility on dry land can be done by increasing C-Organic, one of which is the application of organic fertilizer. Organic materials added to the soil can increase the C-organic content in the soil, also can maintain soil moisture levels. In general, organic materials contain nutrients N, P and K as well as other micronutrients needed by plants. The application of organic fertilizer combined with inorganic fertilizers at the right dosage also has the potential to obtain optimal crop production (Putra *et al*., 2024). The Central Statistics Agency (BPS, 2022) noted that the area of rice fields in Indonesia in 2021 was 10,411,801.22 ha and the rice fields in Indonesia are mostly the result of opening dry land (Putra *et al*., 2024). Heryani & Rejekiningrum (2019) stated that the area of dry land in Indonesia reached 144.47 million ha, and around 99.65 million ha (68.98%) is potential land for agriculture. Meanwhile, the area of dryland, consisting of dry fields (dry fields), hereinafter referred to as dryland rice fields, covers approximately 1,244,906 hectares (Yulianto, 2020). Therefore, dryland in Indonesia has enormous potential for development to support food security, particularly rice.

Challenges to rice cultivation include excessive water requirements, both during soil preparation, the growing period, and before flowering, as well as ongoing land conversion (Widata *et al*., 2023; Ayun *et al*., 2020). Meanwhile, the islands of Java and Bali, which contribute 60% to national rice production, have experienced a water deficit and land conversion since 2010 (Thoriq & Sampurna, 2016). The rate of land conversion in Indonesia averages 10,000 ha/year, with 8,346.65 ha/year occur in Java and 2,269.75 ha/year in outside Java (Purbiyanti *et al*., 2017).

To produce 1 kg of grain, rice plants require approximately 2,500 liters of water, including runoff due to evapotranspiration, seepage, and percolation (Widodo *et al*., 2022) This requirement can be reduced in dryland areas by providing interval irrigation. This increases the water use efficiency index by up to 37.6%. Similar research also shows that intermittent irrigation can reduce water use by 22-76% and increase water use efficiency by 15% to 346% without reducing rice yields (Herdiyanti *et al*., 2021). Water management is a key factor in rice cultivation techniques, and the sustainability of dryland rice production systems can only be maintained by increasing water use efficiency.

Dryland upland rice can grow and produce in conditions with soil moisture below field capacity, with a water requirement of 4-6 mm, or rainfall exceeding 100 mm (Supijatno *et al*., 2012). This water-saving principle for upland rice can be used as a basis for cultivating other rice varieties on dry land. Water-saving techniques, using moisture below field capacity in lowland rice cultivation, can be implemented at all stages of plant growth and even in the pre-harvest phase. Given the limited water availability, prolonged droughts, and the persistence of extensive dry land, the principle of water efficiency in dryland rice cultivation is crucial.

Trials of several rice cultivars suitable for planting in drylands and paddy fields are always carried out with the aim of obtaining rice cultivars that can grow well in paddy fields or drylands with high yield potential (Sanjaya *et al*., 2023). Superior rice varieties are one of the success factors in increasing rice production in dry/rainfed land in Indonesia (Marina *et al*., 2023). The Ciherang rice variety is a rice variety commonly planted in wet paddy fields, this is shown by its use in the mina padi system (Ahmadian *et al*., 2021). New superior rice varieties such as Ciherang are expected to continue to increase productivity because they can adapt to ecosystem conditions, especially in drylands (Wahyudin & Marina, 2024 and Ruminta *et al*., 2016). The purpose of this study was to determine the agronomic response in both the vegetative and generative phases of Ciherang rice plants due to efficient water provision as a benchmark for rice cultivation in drylands. The benefits of this research are to develop and increase rice productivity in dry land and as a basis for sustainable rice cultivation strategies while supporting national food security, optimizing water use, and developing rice varieties suitable for dry land.

2. MATERIALS AND METHODS

2.1. Research Site

This research was conducted on the land of the "Lestari Makmur" farmer group on Jalan Wates Km. 12, Semampir Hamlet, Argorejo Village, Sedayu District, Bantul Regency, Yogyakarta Special Region, for three months. The research location was the Self-Help Agricultural and Rural Training Center (P4S), which had quite complete equipment and several field staff to support research activities in the field. The tools used in this study were buckets, hoes, shovels, hoses, scales, polybags, trowels, nameplates, staples, rulers, tape measures, ovens, carts, measuring cups (300 ml, 600 ml, and 900 ml), and stationery. The materials used included Ciherang rice seeds, cow manure, urea fertilizer, soil, pesticides, and water.

2.2. Experimental Design

The study was conducted using a Completely Randomized Design (CRD). Preliminary research showed that soil in polybags requires an average of 1,350 ml of water to reach supersaturated moisture levels (above field capacity), while rice plants require approximately 2,500 liters of water to produce 1 kg of grain (Widodo *et al*., 2022). Based on these two factors, the researchers designed the following treatment combinations: Factor 1 was water efficiency by deficit irrigation treatment [C1 = 300 ml (efficiency 88.12%), C2 = 600 ml (efficiency 76.24%), and C3 = 900 ml (efficiency 64.36%). Water efficiency treatments were conducted every two days (moisture conditions below field capacity). Factor 2 was fertilizer treatment [D1 = 80% Cow Manure (31.4 g) + 20% Urea (7.85 g), D2 = 50% Cow Manure (19.625 g) + 50% Urea (19.625 g), and D3 = 20% Cow Manure (7.85 g) + 80% Urea (31.4 g)]. Based on these two treatment factors, nine treatment combinations were obtained: C1D1, C1D2, C1D3, C2D1, C2D2, C2D3, C3D1, C3D2, and C3D3. Each combination had three replications, each with five experimental plants, for a total of 135 plants planted in 135 polybags. Figure 1 documented activities performed during research.

Figure 1. Left to right: Planting, fertilization, and plant height measurement

2.3. Implementation Procedure

The rice variety used was the Ciherang variety. The Ciherang rice variety used is not an upland rice variety, but this variety can adapt according to ecosystem conditions, especially in dry land (Wahyudin & Marina, 2024; Ruminta *et al*., 2016). The advantages of the Ciherang rice variety are resistance to brown planthopper biotype 2 and bacterial leaf blight strains III and IV, an average production of 6.0 tons/ha, long, slender grain shape and moderate category shedding. The type of soil used in this study is regosol soil, the radius of the polybag is 0.25m, so the area of the polybag is 0.19625 m² and one polybag is occupied by one clump of rice.

2.4. Observations and Measurements

a. Vegetative Phase

- ***Plant Height:*** Plant height was measured from the base of the stem to the growing point in centimeters (cm). Plant height was measured once, at harvest time.
- ***Number of Tillers:*** The number of rice tillers was measured by counting each clump of sample plants. This observation was carried out once, at harvest time.
- ***Dry Weight of Rice Stover:*** The dry weight of rice stover was obtained after weighing the wet stover, then drying it in the sun for approximately 7 days and using an oven at 105°C for 2 days. Afterward, the stover was weighed in grams, and the drying process continued until the weight remained constant.

b. Generative Phase

- ***Percentage of Filled Grain:*** The weight of filled grain was measured after the rice was harvested by weighing the filled grain yield per clump and expressed in grams.
- ***Grain Weight :*** Grain weight was measured after the rice has been harvested by weighing the grain yield per clump and expressing it in grams.

2.5. Data Analysis

Observations were analyzed using analysis of variance at a 5% level, followed by Duncan's Multiple Range Test (DMRT) at $\alpha = 5\%$ (Sugiyono, 2019).

3. RESULTS AND DISCUSSION

The research results consist of the vegetative phase of rice plants (plant height, number of tillers, dry weight of stalks) and the generative phase of rice plants (percentage of filled grains and grain weight per clump). The data obtained are presented in the following table:

3.1. Vegetative Phase

The results of the study in Table 1 show that Ciherang rice plants remained alive and grew well even though they were irrigated with soil moisture levels below field capacity. The results also showed no interaction between fertilizer treatment and water efficiency treatment on the three observation variables of the vegetative phase (plant height, number of tillers, dry weight of rice stover). Likewise, there was no significant difference between fertilizer treatment and water efficiency treatment. This reflects that the combination treatment of organic cow fertilizer and urea at various doses, as well as variations in water efficiency treatment, had the same effect on the development of plant height, number of tillers and dry weight of rice stover. The water efficiency treatment of 300 ml every two days, the effect on Ciherang rice plants, will be the same as the water efficiency treatment of 600 ml or 900 ml every two days. Rice plants require approximately 2,500 liters of water to produce 1 kg of grain. Meanwhile, research on three rice varieties (Mapan P-05, Intani 602, and SL-8SHS Sterling) yielded an average grain weight per clump of 43.73 grams (Syarifah *et al*., 2022). Referring to this, producing 1 kg of grain requires 23 clumps of rice and requires 45 water applications over a three-month period. Therefore, applying 300 ml of water every two days will require a total water requirement of 310.5 liters, resulting in a water savings or efficiency of 88.12%, as water usage is only 11.88%. Meanwhile, applying 600 ml of water every two days will require a total water requirement of 621 liters and 900 ml of water every two days will require a total water requirement of 931.5 liters, resulting in water savings of 76.24% and 64.36%, respectively.

Table 1. Vegetative phase of rice plants (plant height, number of tillers, dry weight of biomass)

Treatment	Variable		
	Plant Height (cm)	**Number of Tillers (clump)**	**Dry Weight of Biomass (g)**
Fertilizer Combination			
80 + 20 (D1)	97.56 a	20.00 a	43.61 a
50 + 50 (D2)	99.11 a	20.11 a	50.07 a
20 + 80 (D3)	97.56 a	18.44 a	50.05 a
Water Efficiency			
300 ml (C1)	97.00 p	19.44 p	46.10 p
600 ml(C2)	99.00 p	20.33 p	48.63 p
900 ml(C3)	98.22 p	18.78 p	49.00 p
	(-)	(-)	(-)

Note: Mean values followed by the same letters in the same row or column indicate no significant difference according to DMRT at 5% level. (-): no interaction.

Table 2. Analysis of variance (ANOVA) for vegetative phase

Source of Variation	Plant Height		Number of Tillers		Dry Weight of Biomass	
	***F* Value**	***Pr > F***	***F* Value**	***Pr > F***	***F* Value**	***Pr > F***
Fertilizer combination	0.49	0.6198	0.95	0.4036	1.26	0.3066
Water Efficiency	0.62	0.5495	0.67	0.5242	0.23	0.7994
Fertilizer Combination × Water Efficiency	0.42	0.7896	0.39	0.8120	1.01	0.4274

3.2. Generative Phase

The results of the research for the generative phase are shown in Table 3 and Table 4, indicating that there is an interaction between the combination of fertilizer treatment and water efficiency treatment on the harvest yield: filled grain percentage (%) and grain weight (g/clump). The best interaction in the generative phase for the Ciherang variety

Table 3. Mean percentage of filled grains (%)

Combination of Cattle Manure + Urea	Water Efficiency (ml)		
	300(C1)	600(C2)	900(C3)
80 + 20 (D1)	71.77 b	79.68 ab	80.37 ab
50 + 50 (D2)	77.89 ab	81.87 a	71.61 b
20 + 80 (D3)	80.49 ab	77.99 ab	79.57 ab

Note: Mean values followed by the same letters in the same row indicate no significant difference according to DMRT at 5% level.

Table 4. Mean weight of grain per clump (g)

Combination of Cattle Manure + Urea	Water Efficiency (ml)		
	300(C1)	600(C2)	900(C3)
80 + 20 (D1)	41.143 bc	38.133 dc	39.590 cd
50 + 50 (D2)	44.383 a	45.530 a	42.027 b
20 + 80 (D3)	36.550 c	38.153 dc	37.950 dc

Note: Mean values followed by the same letters in the same row indicate no significant difference according to DMRT at 5% level.

Table 5. Analysis of Variance (ANOVA) for Generative Phase

Source of Variation	Percentage of Filled Grains (%)		Weight of Grain per Clump (g)	
	F Value	*Pr>F*	*F* Value	*Pr>F*
Fertilizer combination	0.67	0.5220	**82.14**	**<.0001**
Water efficiency	1.23	0.3152	1.61	0.2265
Fertilizer combination × Water efficiency	**3.08**	**0.0427**	**7.10**	**0.0013**

occurred in C2D2 (water efficiency treatment of 600ml every two days with a combination of 50% organic fertilizer and 50% urea). In the graphs in Figure 1a and Figure 1b, it can be seen that excessive irrigation deficit (300 ml) results in a low % of filled grain and grain weight per polybag. A low irrigation deficit (900 ml) also results in a low % of filled grain and grain weight per clump, even lower than an excessive deficit. A moderate irrigation deficit (600 ml) results in the highest % of filled grain and grain weight per polybag. This means that irrigation deficit (water saving) is good to do but should not be excessive. Thus, it can be said that the success of planting wetland rice (not upland) with irrigation deficit conditions proves that there is an opportunity to develop this rice with a dryland (upland) rice cultivation system and this is a good innovation to be developed. The best interaction resulted in a percentage of filled grain of 81.87%, and a grain weight per clump of 45.53 grams or equivalent to 7.2 tons/ha (assuming a planting distance of 25 cm × 25 cm so that the number of clumps per hectare is 160,000).

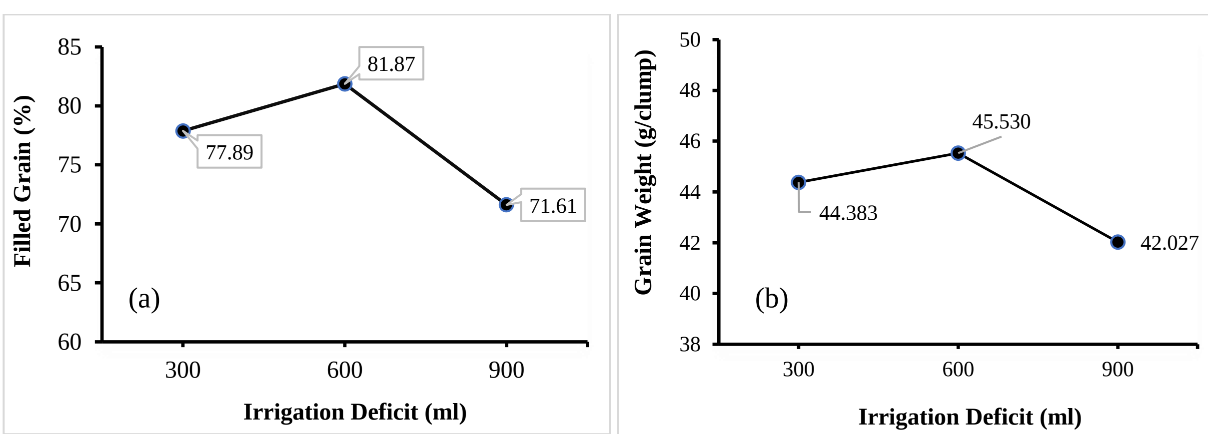

Figure 1. Effect of deficit irrigation on generative parameters at fertilizer ratio (50:50): (a) Percentage of filled grain (%), (b) Grain weight (g/clump)

The yield of grain weight per clump of 45.53 grams is still higher than the results of research on 3 rice varieties (Mapan P-05, Intani 602 and SL-8SHS Sterling) which is 43.73 grams per clump of rice (Syarifah, *et al*. 2022). This shows that Ciherang rice has the potential and is able to adapt to being planted in dry land. Providing 600 ml of water efficiency every two days is the best, meaning that the soil moisture content is still in the field capacity moisture condition and can save water or provide an efficiency of 76.24%. The combination of 50% manure and 50% urea will provide a balanced dose, can provide optimal nutrients to support plant growth and increase yields. This is in line with the statement of Zahrah (2011) where increased yields in rice plants can occur due to the optimal availability of N, P, K nutrients so that plant vegetative growth, photosynthesis processes and photosynthates translocation can take place well. Likewise, a balanced combination of cow manure and urea will support the plant production process. Rachmadhani *et al*. (2014) stated that the balance of organic and inorganic fertilizer use is the key to proper fertilization. Inorganic fertilizer is a quick way to increase plant productivity, while organic fertilizer will be able to improve the physical, chemical and biological properties of the soil. The presence of organic fertilizer can maintain field capacity moisture. This aligns with research by Sulistyono & Abdillah (2017), which found that adding 25% organic fertilizer, 50% rice husks, and digging holes increased field moisture capacity by 42.7%.

The best interaction for water efficiency treatments occurred with the 600 ml treatment every other day. This indicates that the 600 ml water efficiency treatment provides sufficient water availability to meet the water needs of the Ciherang rice plant's generative phase. Producing 1 kg of Ciherang rice grain with the 600 ml water treatment every other day requires a total of 621 liters of water, resulting in a water savings of 76.24%, far below the water requirement for producing 1 kg of rice, which is approximately 2,500 liters. Herdiyanti *et al*. (2021) also stated that the Ciherang variety can produce high yields during drought. Water is essential for rice plants during their growth phases, especially during seed filling. If the plant enters the seed filling phase and lacks water, seed production will be disrupted (Fadhilah *et al*., 2021).

4. CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate a significant interaction between water efficiency through deficit irrigation and fertilizer ratio in the generative phase, but no significant interaction was found in the vegetative phase. Furthermore, the combination of 600 ml of water irrigation (efficiency of 76.24%) and a fertilizer of 50% cow manure + 50% Urea resulted in the highest percentage of filled grain and filled grain weight. These results indicate that Ciherang rice can grow well under water-efficient conditions, thus having the potential for cultivation in dryland areas. This study can be used as a follow-up for other rice varieties, potentially leading to the development of many varieties that can be recommended for dryland cultivation.

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