Response of different local Rice varieties to shallow water depth irrigation in Indonesia

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Abstract. Shallow water depth (SWD) and intermittent irrigation are methods designed to reduce water use of rice plant and maintain rice yield. The objective of this study was to characterize the rice plant growth behaviour of four different local rice varieties cultivated in continuous flooding (CF) and intermittent with shallow water depth (SWD) irrigation. Rice varieties i.e. Ciherang, IR64, Hitam, and Merah were grown in pot experiment with CF and SWD irrigation. Rice growth parameters such as plant height, number of tillers, SPAD, and steam hardness were observed during a season. Different rice varieties resulted different response to irrigation treatment, where Ciherang and Merah varieties under SWD irrigation were significantly improved number of tillers. However, IR64 and Hitam varieties were different. In addition, plant height and SPAD were not significantly different among treatment. Rice cultivation under SWD irrigation of different local rice varieties in this experiment shows that not significantly different from CF irrigation, indicated that rice varieties can be adapted in areas with limited water availability.

1. Introduction
Indonesia is known as an agricultural country where most of the population works in the agricultural sector. Indonesian people use rice as one of the staple foods. Based on data from the Badan Pusat Statistik (BPS) in 2010 Indonesia's population has reached 237,641,326 inhabitants. An increase of population causes increase in food needs. In addition, the need for housing will also increase. The increasing need for Indonesians every year regarding land has led to the conversion of agricultural land where since 2013 the area of agricultural land has fallen by 0.5% per year [1]

Rice is one of the main food sources in Indonesia in addition to corn, sago, and tubers. In Indonesia, there are several varieties that are often planted by farmers, including superior rice varieties such as IR64, Ciherang and local rice such as Merah, Hitam [2]. Rice was planted in 2 methods, namely, conventional methods and System of Rice Intensification (SRI). The SRI planting pattern seeks to improve the function of the soil as a growth medium and source of plant nutrients, while maintaining and promoting ecological values themselves. The application of the SRI method seeks to reduce the use of input from outside to increase rice production. In SRI there are three (3) main points i.e (1) selection of rice seed; (2) land management; (3) the role of microorganisms and compost.

Previous study resulted that rice cultivation under SWD framework with alternations of aerobic and anaerobic condition during rice plant growth was greater than continuous flooding as well as rice yield.
Compared to continuous flooding irrigation, SWD provides a different growth environment. During the growth period, rice plants need water as a support for their growth. The process of transpiration and evaporation affects how much water is lost other than those absorbed by rice plants. Water loss through the process of evaporation and transpiration is commonly referred to as evapotranspiration. Evapotranspiration is also referred to as the amount of water needed by plants. Previous study by [5] reported that rate of evapotranspiration of plants are stomatal closure, number and size of stomata, number of leaves, rolling or folding of leaves, and root depth. Moreover, evapotranspiration is an indicator of plant growth. This research aims to characterize the rice plant growth behavior of four different local rice varieties cultivated in continuous flooding (CF) and shallow water depth (SWD) irrigation.

2. Methodology

2.1. Experimental Site
The research was conducted at Agro Technology Innovation Center of Universitas Gadjah Mada, Sleman, Yogyakarta (7° 47’ 47” S dan 110° 27’ 49” E) with altitude 96 m above sea level since January until May 2019. The experiment was used a Completely Randomized Design. Different rice varieties namely Ciherang, IR-64, Merah, and Hitam were cultivated in two irrigation treatment, (1) shallow water depth water and (2) continuous flooding. Under shallow water depth (SWD) rice was irrigated by 1 – 2 cm water in every pot, whereas continuous flooding (CF) was irrigated 5 cm water depth during plant growth season.

In this research, rice planting was carried out on 1 planting pot per rice seed. The experimental pot has a diameter of 30 cm, with a soil depth of about 20 cm. Soil has sand (2%), silt (81%), and clay (17%) categorized as silty loam soil. Rice seeds are sown on soil mixed with compost in a ratio of 1 : 1 for 7-14 days. Seedlings that are 7-14 days old are then transferred to the cultivated media. Compost fertilizer was given at the initial processing of 90 grams per pot, then NPK fertilizer was given at a dose of 1.35 grams per pot after the seeds were 30 days after planting (HST).

Parameters measured include microclimate (solar radiation, temperature, relative humidity, wind speed); plant physiology (plant height, number of tillers, SPAD).

2.2. Data analysis
Climatic parameters, temperature, relative humidity, wind velocity, and solar intensity were measured everyday by automatic weather station. Annova two way and graph analysis were adopted to compare different rice growth. Mathematical model was used to predict rice plant growth. According to [7], plant growth modelling uses monomolecular functions and polynomial exponent functions.

3. Results and Discussion

3.1. Climatic condition
Experimental site was a tropical area with temperature ranged from 27.8° – 41.65° C, where suitable for rice cultivation (Fig 1). Refer to [8], minimal temperature for rice cultivation was about 11° - 25° C. During initial phase (30 days after planting), solar radiation was low due to rainy season in Indonesia (Fig 2). Average relative humidity (RH) was 69.89% with minimum value 46.7%. moreover, maximal wind speed was 0.9 m/s (Fig 3).
Figure 1. Temperature and relative humidity

Figure 2. Solar radiation and intensity

Figure 3. Wind velocity
3.2. Plant Growth

Plant height in different variety under SWD was higher than CF treatment (Table 1). Statistically, plant growth was not significantly affected by different treatment ($p>0.05$). According to [9], with the presence of nutrients with sufficient levels and balanced for the process of plant growth, division, photosynthesis, and elongation of cells will take place quickly which will result in some organs of plants growing rapidly, especially in the vegetative phase. In the SRI method, the soil gets good aeration because the soil is not inundated continuously only at certain times, while the conventional treatment is inundated continuously which causes the soil not getting sufficient aeration. Roots need oxygen from the soil for the breathing process and growth so that with the SWD method the roots get sufficient aeration so that the plant growth process can take place maximally. The inundated plants will show the characteristic chlorosis typical of N deficiency. Deficiency of N occurs due to a decrease in the availability and absorption of N. When inundated, the availability of N in the form of nitrate is very low due to the process of denitrification. The inundation will have a negative impact on the availability of N, besides the inundation also affects physiological and biochemical processes including respiration, root permeability, absorption of water and nutrients by roots, embedding N.

| Varieties | SRI (cm) | Conventional (cm) | Mean (cm) |
|-----------|----------|-------------------|-----------|
| Ciherang  | 68,2     | 65,5              | 66,9      |
| IR64      | 68,2     | 71,8              | 70,0      |
| Hitam     | 64,9     | 66,8              | 65,9      |
| Merah     | 71,0     | 66,6              | 68,8      |

Based on Table 2, the highest number of productive tillers for each variety was Ciherang (SWD), IR64 (CF), Hitam (CF), Merah (SWD). SWD and CF treatments with an influence on the number of rice tillers are mutually have the same opportunity or have an opportunity with a percentage of 50:50 so that the SWD and CF treatments will affect certain varieties. According to [10] the number of tillers will have maximum results if the plants have good genetic traits and are supported by environmental conditions that are good or in accordance with the growth and development of these plants. According to [11], rice plants tend to be fast in the process of forming tillers if the availability of water and nutrients is sufficient and supported by a suitable environment such as sufficient sunlight intensity and optimum temperature. Another factor that affects the number of tillers according to [12], which is the wide spacing, with a wide spacing will increase solar radiation captured by the canopy so that plant growth will increase.

| Varieties | SRI | Conventional | Mean |
|-----------|-----|--------------|------|
| Ciherang  | 8,6 | 4,9          | 6,8  |
| IR64      | 7,7 | 11,5         | 9,6  |
| Hitam     | 8,2 | 9,4          | 8,8  |
| Merah     | 9,0 | 6,8          | 7,9  |

Moreover, the highest SPAD value was obtained from conventional treatments (Table 3). This shows that in conventional treatment the leaf chlorophyll value is high, whereas in the SRI treatment the leaf chlorophyll value tends to be low. According to [13], the function of chlorophyll in plants is to absorb light and transfer through plants during photosynthesis. With the abundance of chlorophyll in plants it will affect the rate of photosynthesis which will cause an increase in the amount of water needed in plants.
### Table 3. SPAD Value

| Varieties | SPAD SRI | Konvensional | Mean |
|-----------|----------|---------------|------|
| Ciherang  | 32.4     | 38.7          | 35.6 |
| IR64      | 30.5     | 30.1          | 30.3 |
| Hitam     | 30.1     | 37.8          | 34.0 |
| Merah     | 30.0     | 30.8          | 30.4 |

![Figure 4. Chart of SPAD](chart.png)

#### 3.3. Plant Growth Rate

Monomolecular function was used to determine plant growth rate by using plant height data. Coefficient \(k\) and correlation coefficient \(R\) presented in Table 5. In the SWD treatment, the highest parameter value in the Merah variety with a coefficient value of \(k\) 0.0314 and the value of the correlation coefficient \(R^2\) 0.9731. In the CF treatment, the highest parameter value is in the IR64 variety with a coefficient value of \(k\) 0.031 and a correlation coefficient value of \(R^2\) 0.9611. It can be concluded that with the correlation coefficient \(R^2\) obtained, it can be said to be potent, then the age of the plant will affect the height of the rice plant.

### Table 4. Coefficient value of \(k\) and \(R^2\)

| Varieties | coef k | \(R^2\) |
|-----------|--------|--------|
| Ciherang  | 0.0271 | 0.9678 |
| IR64      | 0.0262 | 0.9682 |
| Hitam     | 0.015  | 0.9349 |
| Merah     | 0.0314 | 0.9731 |

The obtained \(k\) parameter values are used as coefficients to find the high value of the predicted plant. Furthermore, the predicted plant height is obtained by using a certain formula so that the value of plant height prediction is obtained. Then each variety and treatment was plotted as variable \(y\), for plant age as variable \(x\). There was no significant difference between the height of the observation plant and the height of the predicted plant in the treatment of SWD and CF treatments. This means that the two methods show that plant height has good growth. Furthermore, the height of the observation plant and the
predicted plant height were validated. Validation is done by observing plant height as x variable, while plant height is predicted as y variable.

| Table 5. Plant Height Validation |
|-------------------------------|----------------|
| Varieties | coef k | R² |
| Ciherang SRI | 0.9596 | 0.984 |
| Conventional | 0.9456 | 0.9562 |
| IR64 SRI | 0.9412 | 0.9769 |
| Conventional | 1.0016 | 0.9815 |
| Hitam SRI | 0.8284 | 0.9283 |
| Conventional | 0.857 | 0.9488 |
| Merah SRI | 0.9313 | 0.9828 |
| Conventional | 0.9196 | 0.9787 |

SWD treatment has a correlation coefficient value R² of more than 0.9 with the highest value of 0.98 in the Ciherang variety which means that between the height of the observation plant and the height of the predicted plant has a strong association relationship. This is evidenced because the correlation coefficient value R² approaches 1. In the conventional method the correlation coefficient value R² is more than 0.98 with the highest value of 0.9901 in the Hitam variety. This means that between high observation and high predictions there is no significant difference. With the coefficient of correlation R² approaching 1, it can be said that the method is suitable. This means that the use of monomolecular equations is suitable for the predictions of rice height.

There are differences in the rate of growth of the number of predictive tillers both in SWD and CF. To find out the growth rate of the number of tillers, polynomial equations are used to determine the number of tillers. Tillers data are used to calculate predictions using mathematical models with polynomial equations. It can be seen that the coefficient value of R² in the SRI method is more than 0.847 with the highest coefficient value R² is 0.9379 in the IR64 variety, whereas in the conventional variety the coefficient value R² is known to be more than 0.76 with the highest coefficient value R² is 0.9567 in the Merah variety. It can be concluded that the model can adequately describe the growth of rice plants with R² values that are strong enough to approach 1. Then the coefficient value R² and the coefficient parameters a₀, a₁, a₂ are summarized in Table 7.

| Table 6. The exponential model function of rice plant tillers number |
|----------------|----------------|
| Method | varieties | a₀ | a₁ | a₂ | R² |
| SRI | Ciherang | 0.3668 | 0.0607 | -0.0004 | 0.847 |
| IR64 | 0.2592 | 0.0607 | -0.0004 | 0.9379 |
| Hitam | 0.7387 | 0.059 | -0.0005 | 0.8842 |
| Merah | 0.4638 | 0.0603 | -0.0004 | 0.894 |
| Conventional | Ciherang | 0.4897 | 0.0412 | -0.0003 | 0.76 |
| IR64 | 0.1147 | 0.0805 | -0.0006 | 0.8771 |
| Hitam | -0.1957 | 0.0824 | -0.0006 | 0.8972 |
| Merah | 0.1163 | 0.0625 | -0.0005 | 0.9567 |

The parameter values a₀, a₁, a₂ obtained from the polynomial equation are used as references to calculate the number of prediction tillers. With a certain formula and by entering the parameter values a₀, a₁, a₂ to the specified formula, the value of the number of prediction tillers is obtained. The next data is graphed between the number of observation and prediction tillers.
There are several differences between the number of observation tillers and the number of predictive tillers, but the value of predictive data is not too far from the real conditions in the field. This is enough to illustrate how the growth rate of rice tillers number during the planting period. From the data between the tillers number and the predictive tillers number then graphed of time which is then validated. The number of tillers was observed as the x variable, and the number of predictive tillers as the y variable which then searched for $R^2$.

| Varieties | R$^2$   |
|-----------|---------|
| Ciherang  | 0.7044  |
| IR64      | 0.7344  |
| Hitam     | 0.8416  |
| Merah     | 0.7207  |
|           | 0.8306  |
|           | 0.8509  |
|           | 0.8238  |
|           | 0.8403  |

In the SRI method, the lowest $R^2$ value was 0.7044 in the Ciherang variety and the highest value was 0.8416 in the IR64 variety. In the conventional method, the value of $R^2$ is 0.7207 on the IR64 variety and the highest value $R^2$ is 0.8509 on the Hitam variety. With $R^2$ value that is more than 0.7, close to 1, it can be concluded that the function of the polynomial exponent is sufficient to calculate the predicted value of the tillers number.

4. Conclusion
In response to plant growth such as plant height, number of tillers, SPAD, stem hardness is influenced by differences in water treatment. Different rice varieties resulted different response to irrigation treatment, where Ciherang and Merah varieties under SWD irrigation were significantly improve number of tillers. However, IR64 and Hitam varieties were different. In addition, plant height and SPAD were not significantly different among treatment. Modeling of plant height growth responses is suitable using the monomolecular function equation. Modeling of the number of tillers growth responses is suitable using the polynomial exponent function equation. Rice cultivation under SWD irrigation of different local rice varieties in this experiment shows that not significantly different from CF irrigation, indicated that rice varieties can be adapted in areas with limited water availability.

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