Leaf area index development of local rice varieties as a response to different irrigation management

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Abstract. Rice is a semi-aquatic plant and grown under anaerobic condition as long as water is available. Nowadays, water scarcity and climate change issues need to address with new technology to increase water use efficiency in rice production. In the other hand, rice varieties must be able to adapt climate change in the future, especially drought even during rice growth periods. A shallow water depth irrigation, as a strategy to reduce water use might influence the rice growth development. The aim of this study was to characterize the leaf area index development of three different rice varieties grown in continuous flooding and shallow water depth irrigation. Pot experiments were conducted in Yogyakarta, Indonesia with three different rice varieties, i.e Mutiara, IR 64, and Hitam, and cultivated with two different irrigation system namely shallow water depth (SWD) and continuous flooding (CF). Leaf Area Index (LAI) was measured every 10 days and polynomial equation was used to describe LAI development during plant growth. Analysis of variance (ANOVA) was performed using Ms. Excel to determine significant differences between treatments (p < 0.05). Pearson correlation coefficient (R) was used to evaluate the performance of mathematical model. Leaf Area Index (LAI) under shallow water depth irrigation in different rice varieties were not significantly different compare to continuous flooding irrigation. LAI development in different treatment were described by polynomial equation, with various correlation value, ranged between 0.46 – 0.88. IR64 variety under control irrigation resulted lowest R (0.46), indicated that prediction value from observation data was not strongly correlated. However, other treatments showed strong relationship between prediction and observation data.

1. Introduction
Rice as a staple food in Indonesia is a semi-aquatic plant and grown under submerged condition when water is available. Traditional farmer in Indonesia normally use continuous flooding with chemical fertilizer for their rice cultivation. Nowadays, with increasing of water scarcity and environmental issues due to high input of chemical in agricultural field, it is necessary to improve and optimize of water and fertilizer managements for rice cultivation. Therefore, various water saving irrigation techniques have been developed in different countries to maintain acceptable rice yields [1–3]. Saturated soil culture or shallow water depth (SWD) is an emerging technology by irrigating to about 1 cm water depth a day to enhance water use efficiency under rice production [4,5].
In previous study, rice cultivation under SWD framework with alternations of aerobic and anaerobic condition during rice plant growth was greater than continuous flooding. Rice yields under SWD also higher than conventional [6]. Compared to continuous flooding irrigation, SWD provides a different growth environment. Alternation between aerobic and anaerobic condition resulted favorable soil redox potential (Eh) in the rhizosphere to support rice plant growth [6,7]. Moreover, [1] also reported that water use efficiency of rice was increased under SWD.

Although SWD irrigation and alternate wetting and drying culture was resulted positive impact on rice cultivation as mention above, studies on rice physiology in different rice varieties under SWD and alternate wetting and drying culture have been scarcely reported, especially in Indonesia. Different irrigation technique in rice cultivation will give different effect on rice physiology. Leaf is the main organ of plant and responsible to plant photosynthesis. Development of leaf area described light interception, which could affect photosynthetic rates. Besides providing indication of photosynthetic, leaf area also was an indicator to understand plant responses in different environmental condition [8]. This research was aimed to characterize the leaf area index development of three different rice varieties grown in continuous flooding and shallow water depth irrigation.

2. Materials and Methods
2.1. Experimental site
Pot experiment was carried out in the screen house of Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia (latitude: 7º46'05,0" S, longitude: 110º22'48,1" E) with altitude 139 m above sea level in dry season (April to July 2018). This area has tropical monsoon climate with average temperature during experiment ranged from 26.75 – 27.76°C, relative humidity was 72.96 – 79.22 %, wind velocity 0.87 – 0.97 m/s, and solar intensity 155.4 – 174.38 lux.

2.2. Experimental design
This study was laid out in a randomized block design with three replications. Local rice varieties (Hitam and Mutiara) and IR 64 variety were grown in pot experiments with diameter 30 cm. Two different irrigation regimes, shallow water depth (SWD) and continuous flooding (CF) were conducted during plant growth. CF was conducted as control treatment followed local farmer cultivation system. Soil for pot experiment was taken from rice field near Yogyakarta, Indonesia with depth 0-30 cm. The soil was clay (32% sand, 25% silt, and 43%clay) with bulk density (BD) was 1.36 gr/cc, specific gravity (SG) was 2.57, C-organic was 2.65 %, N-total 0.11 %, and P$_2$O$_5$ was 45 ppm. Soil was homogenized in the pot before transplanting.

Rice was planted with young seedling (12 days after nursery) and one seed for every pot followed System of Rice Intensification (SRI) framework. Irrigation was added every day to maintain water depth in the pot experiment. SWD was 1 cm during vegetative phase and 5 cm during generative phase. Further, CF was 5 cm during vegetative and generative phase. In this study, fertilizer application was similar both in SWD and CF treatments. Organic fertilizer as basal fertilizer (2 ton/ha), which equivalent to 200 gr/pot applied a week before transplanting. Organic fertilizer was compost from manure. For additional fertilizer, also used organic fertilizer with 1 ton/ha or equivalent to 100 gr/pot applied 30 days after transplanting.

2.3. Properties measurements
Leaf area index (Eq. 1) was determined by measuring leaf area of rice plant, by planimeter

\[
\text{LAI} = \frac{\text{Leaf area}}{\text{Total shaded area}}
\]  

(1)

Mathematical model was developed to describe plant growth phenomena. In this study, polynomial equation (Eq. 2) was used to describe LAI development in different treatment. This equation provides a tool for understanding the characteristic of rice plant growth in various locations and treatments.
\[ W = \exp(a_0 + a_1 t + a_2 t^2 + a_3 t^3 + \ldots) \]  
(2)

Where \( W \) is the growth function at time \( t \) and \( a \) is parameter.

2.4. Statistical analysis
Analysis of variance (ANOVA) was performed using Ms. Excel to determine significant differences between treatments (\( p < 0.05 \)). Pearson correlation coefficient (R) was used to evaluate the performance of mathematical model.

3. Results and discussion
3.1. Leaf area index development in different rice varieties and irrigation management
In this study, we found that leaf area index (LAI) was varied among treatment. The LAI showed an increasing trend from initial growth stage up to 60 DAP (vegetative phase) and afterwards it showed a decreasing trend up to final stage. The effect of irrigation treatments on LAI in different rice varieties was consistent over the crop growth stages. Generally, IR-64 variety was significantly having lower LAI (0 – 1) than Hitam and Mutiara varieties (0 – 2.5), both under SWD and CF irrigation (Fig 1, 2, and 3). Different rice varieties might respond differently to different irrigation water level both physiological and biochemical behavior [9].

Mutiara variety under CF irrigation tend to be higher than SWD irrigation (\( p<0.05 \)) (Fig 1). Maximum value of LAI was achieved at vegetative phase (40 – 60 DAP), where CF was 2.63 and SWD was 1.97. Moreover, LAI of Hitam variety was comparable between SWD and CF (\( p>0.05 \)) (Fig 2). In the other hand, IR-64 resulted different trend where LAI under SWD was higher than CF irrigation (Fig 3).

LAI was an indicator that reflects biochemical and physiological processes of plants. This study described that different varieties of rice showed different behavior as an impact of irrigation treatment. Furthermore, all rice varieties could adapt both in SWD irrigation and CF irrigation. SWD irrigation has a positive impact for water saving. Previous study by [10] [11] found that alternate moderate wetting and drying irrigation (AMWD) regime was helped to save water irrigation about 16% to 28.8% compared to continuous flooding (CI) regime. This water saving was mainly due to differences in the vegetative stage treatments.

![Figure 1. Leaf Area Index (LAI) development of Mutiara variety under shallow water depth and continuous flooding irrigation](image-url)
3.2. Mathematical model of leaf area index in different rice varieties and irrigation management

Polynomial equation analysis was used to predict leaf area index (LAI) in different rice varieties under SWD and CF irrigation (Fig 4, 5, and 6). The polynomial functions were carried from time variables that showed varied result of correlation, ranged from 0.46 to 0.88.

Mutiara variety under SWD and CF irrigation resulted high correlation between observed and predicted model (0.88 and 0.80 respectively) as shown in Fig 4. Hitam variety also shown high correlation (0.81 and 0.86 respectively for SWD and CF). Moreover, IR-64 resulted lowest correlation (0.73 and 0.46 respectively for SWD and CF). Present study resulted that polynomial equation was not proper to describe LAI development of IR-64 variety under CF irrigation.

[12] reported that in the polynomial model, growth function follows a smooth curve, potentially of great complexity. This model can be fit in a linear model framework. However, polynomial model tends
to make false upward or downward prediction, especially at the extremes data. For more precise modeling, environmental factors as well as growth factor should be included in the model.

Figure 4. Observed and predicted LAI of Mutiara variety under shallow water depth (a) and continuous flooding (b) irrigation

Figure 5. Observed and predicted LAI in Hitam variety under shallow water depth (a) and continuous flooding (b) irrigation
4. Conclusion

In this study, IR-64 variety was significantly having lower LAI (0 – 1) than Hitam and Mutiara varieties (0 – 2.5), both under SWD and CF irrigation. Mutiara variety under CF irrigation tend to be higher than SWD irrigation (p<0.05). Maximum value of LAI was achieved at vegetative phase (40 – 60 DAP), where CF was 2.63 and SWD was 1.97. Moreover, LAI of Hitam variety was comparable between SWD and CF (p>0.05). In the other hand, IR-64 resulted different trend where LAI under SWD was higher than CF irrigation.

The polynomial functions were carried from time variables that showed varied result of correlation, ranged from 0.46 to 0.88. Mutiara variety under SWD and CF irrigation resulted high correlation between observed and predicted model (0.88 and 0.80 respectively). Hitam variety also shown high correlation (0.81 and 0.86 respectively for SWD and CF). Moreover, IR-64 resulted lowest correlation (0.73 and 0.46 respectively for SWD and CF). Present study resulted that polynomial equation was not proper to describe LAI development of IR-64 variety under CF irrigation. For more precise modeling, environmental factors as well as growth factor should be included in the model.

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