Comparison of evapotranspiration between continuous flooding and shallow water depth irrigation in different rice varieties of Indonesia

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Abstract. Lowland rice field with continuous flooding irrigation is the predominant rice cultivation system in Indonesia which need high demand of water. Nowadays, water scarcity and climate change issues need to be address with new technology to increase water use efficiency in rice production. This study aims to compare rice seasonal evapotranspiration between continuous flooding (CF) and shallow water depth (SWD) irrigation in different rice varieties. Pot experiments were conducted during rainy season in 2018 at screen house Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia. Three different rice varieties, Hitam, Mutiara, and IR 64 were used in this experiment. Daily reference evapotranspiration (ETo) was estimated using Penman-Monteith equation and the weather variables were collected at the site by an automatic weather station. Irrigation water input were monitored every day and actual crop evapotranspiration (ETa) was determined by using water balance method. ETo during plant growth season was varied from 1.78 mm/day to 3.46 mm/day with average value of 2.64 mm/day. Rice daily ETa was varied among irrigation treatments and rice varieties. ETa of Hitam variety under SWD was varied from 0.90 mm/day to 5.47 mm/day and under CF was 0.71 mm/day to 6.36 mm/day. IR64 under SWD was varied from 1.51 mm/day to 4.20 mm/day and under CF was 0.85 mm/day to 6.51 mm/day. Mutiara was showed higher ETa than Hitam and IR64 both in SWD and CF irrigation with value ranged from 1.46 mm/day to 4.99 mm/day for SWD and 1.13 mm/day to 8.63 mm/day for CF.

1. Introduction
Rice (Oryza sativa L) is an important staple food in Indonesia which normally grown under irrigation system. Agriculture, especially rice is contributing to the excessive water need due to irrigation enhance the evapotranspiration rate from cropping system [1]. Indonesian farmers normally follow continuous flooding irrigation during rice plant growth.

Worldwide, about 93 million ha of irrigated lowland rice provide 75% of the world’s rice production, either continuously flooded, intermittently flooded, or drained [1,2]. Calculation of rice evapotranspiration has shown different values relative to standardized reference evapotranspiration (ETo) as a function of climatic parameters and cultural practice in study area [3].

Nowadays, irrigation water resource has shrunk in many areas due to global population growth, increasing urban, and industrial demand [4]. Moreover, water scarcity and climate change issues need to be address with new technology to increase water use efficiency in rice production. Some researchers developed water-saving irrigation (WSI) techniques for rice cultivation and applied as a...
 mitigation strategy towards water scarcity. In WSI, the soil remains under alternate drying-wetting cycles, which leads to changes in rice evapotranspiration (ET) and crop coefficient (Kc) [5,6]. Compared to the traditional rice cultivation with continuous flooding irrigation, alternate wet and dry irrigation (AWD) as WSI techniques provides different growth environment [7].

Previous study also reported that water-saving irrigation have positive impact on rice plant growth compared with continuous flooding irrigation [5,8]. Furthermore, this irrigation also increased water use efficiency [4]. In this study, different rice variety in Indonesia both local and hybrid rice i.e hitam, IR64, and mutiara are used to compare actual evapotranspiration value under shallow water depth and continuous flooding irrigation.

2. Materials and Methods

2.1. Site and experiment description

Experiment was conducted in 2018 rice growing season (March to June) at the screen house of Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia (latitude: 7°46’05,0” S, longitude: 110°22’48,1” E) with altitude 139 m above sea level. Experimental site was a 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. Different rice varieties i.e. Hitam, Mutiara, and IR 64 was used in this experiment in pot experiments with diameter 30 cm. All varieties were grown in two different irrigation regimes, shallow water depth (SWD) and continuous flooding (CF). 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 1.36 gr/cc, C-organic was 2.65 %, N-total 0.11 %, and P₂O₅ 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.

2.2. Data measurement and analysis

Daily weather variables (temperature, relative humidity, wind speed, solar radiation) were collected at the site by an automatic weather station. Weather variables were used to estimate potential evapotranspiration (ETp). Penman – Monteith equation was used to calculate ETp [9]:

\[
ET_o = \frac{0.408 \lambda (R_n - G) + \gamma \frac{900}{T + 273} u_z (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_z)}
\]  

(1)

Actual evapotranspiration (ETa) was calculated from water balance in the pot. Rainfall was neglected and water input only from irrigation. Water depth in pot was measured every day in every treatment. ETa was calculated by:

\[
ETa = Input - Output
\]  

(2)

3. Results and discussion

3.1. Weather condition
Meteorological condition in the 2\textsuperscript{nd} cropping season 2018 are shown in figure 1 and 2. The daily weather data were recorded in the experimental site. Average temperature was 27.28\(\text{\degree C}\) with minimum temperature was 24.5\(\text{\degree C}\) and maximum temperature was 29.5\(\text{\degree C}\). Relative humidity was ranged from 64.3\% - 92.1\% with average value 75.8\%.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{Daily temperature in the experimental site}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure2.png}
\caption{Daily relative humidity in the experimental site}
\end{figure}

3.2. Evapotranspiration

Daily potential evapotranspiration (ETo) is controlled by weather condition, such as solar radiation, temperature, relative humidity, and wind speed. [10] Reported that about 77 – 92\% of seasonal variation of ET was primarily controlled by net solar radiation (Rn). Daily ETo in the experimental site was ranged from 1.78 – 3.47 mm/day with average value of 2.64 mm/day.

Evapotranspiration depends upon the interaction of weather, plant and soil. The influence of weather alone can be described by reference evapotranspiration (ETo). ETo is defined as the rate of ET from a hypothetical reference crop with a crop height of 0.12 m, a fixed surface resistance of 70 s m\(^{-1}\) and an albedo of 0.23, closely resembling the ET from an extensive surface of green grass of uniform height, actively growing, well-watered and completely shading the ground [9].

Daily Actual Evapotranspiration (ETa) is shown in figure 3 together with daily ETo during 80 Days after transplanting of rice. ETo and ETa of rice was fluctuated during plant growth season. ETa of hitam variety under SWD was higher than CF irrigation. In the initial stage, ETa was lower both in SWD and CF (1.27 and 1.25 mm/day respectively). ETa was increase to maximum value at crop development and mid stage. IR64 variety has similar behavior with hitam variety, ETa under SWD
was higher than CF irrigation in the initial stage (1.94 and 1.28 mm/day respectively). However, ETa of CF was higher than SWD at the crop development and mid stage. Moreover, ETa of Mutiara variety has highest value under SWD treatment at initial stage, but lowest value at crop development and mid stage.

Previous study by [11] reported that IR64 variety under 10 cm water depth irrigation was higher than 5 cm water depth irrigation (1.71 and 1.41 mm/day respectively). Other study by [12] resulted that ETo rates of lowland rice fields were 4 – 5 mm/day in the wet season and 6 – 7 mm/day in the dry season.

![Graphs showing daily evapotranspiration for different varieties and irrigation treatments](image)

**Figure 3.** Daily Evapotranspiration (ETo) and Actual Evapotranspiration (ETc), (a) Hitam variety (b) IR64 variety (c) Mutiara variety under shallow water depth and continuous flooding irrigation

**Table 1.** Daily Actual Evapotranspiration in different rice varieties and irrigation treatment

| Rice variety | ETa SWD (mm/day) | ETa CF (mm/day) |
|--------------|------------------|-----------------|
|              | Mean  | Max  | Min  | Mean  | Max  | Min  |
| Hitam        | 2.87  | 5.47 | 0.90 | 3.01  | 6.36 | 0.71 |
| IR64         | 2.63  | 4.20 | 1.51 | 2.68  | 6.51 | 0.85 |
| Mutiara      | 3.08  | 5.00 | 1.46 | 4.48  | 8.63 | 1.13 |
Although ETa value of Hitam, IR64, and Mutiara was higher under SWD than CF irrigation at the initial stage, total value of ETa under CF irrigation has highest value (Fig 4). The mean, maximum, and minimum daily ETa in different rice varieties and irrigation treatment are given in Table 1. The overall mean daily ETa was observed in Mutiara under CF irrigation (4.48 mm/day). The highest maximum value of ETa also found in Mutiara CF (8.63 mm/day) and the lowest minimum was in Hitam CF (0.71 mm/day). Generally, Mutiara variety showed higher ETa than other variety both in SWD and CF irrigation (figure 4).

**Figure 4.** Total Actual Evapotranspiration (ETa) of Hitam, IR64, and Mutiara varieties under shallow water depth and continuous flooding irrigation

4. Conclusion
Based on calculation of potential evapotranspiration (ETo) by Penman-Monteith equation, ETo in the experimental site was ranged from 1.78 mm/day – 3.47 mm/day with an average of 2.64 mm/day. Daily ETo is controlled by weather condition, such as solar radiation, temperature, relative humidity, and wind speed.

Rice daily ETa was varied among irrigation treatments and rice varieties. Daily ETa of Hitam variety under SWD was varied from 0.90 mm/day to 5.47 mm/day and under CF was 0.71 mm/day to 6.36 mm/day. IR64 under SWD was varied from 1.51 mm/day to 4.20 mm/day and under CF was 0.85 mm/day to 6.51 mm/day. Mutiara was showed higher ETa than Hitam and IR64 both in SWD and CF irrigation with value ranged from 1.46 mm/day to 4.99 mm/day for SWD and 1.13 mm/day to 8.63 mm/day for CF.

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