Microclimate on rice cultivation of local varieties (*Oryza sativa* L.) by intermittent irrigation

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Abstract. This study examines the influence of local varieties and identifies the effects of water-saving intermittent irrigation on microclimate change. This study was compiled using a 3x2 factorial experiment design with a Complete Group Randomized Design. The local rice varieties factor consists of 3 levels: varieties Rojolele, Pandan Wangi, and Mentik Wangi. Factor 2 kinds of irrigation consist of 2 levels, namely: conventional irrigation and intermittent irrigation. The results showed various local rice varieties and types of irrigation no interaction or no mutually affecting relationship to the microclimate change. The air temperature is 29.98 – 36.16°C, while the ground surface temperature is 29.00 – 34.22°C. The surface temperature of the soil and a depth of 25 cm in the maximum vegetative growth phase and at the time of seed formation with intermittent irrigation is higher than conventional irrigation. Pandan Wangi Rice Varieties produce higher grain, although the three local rice varieties do not significantly influence the microclimate change, namely air temperature, humidity, soil temperature, and intensity of sunlight. There is no interaction between local varieties of rice and irrigation types to the microclimate of local rice crops. The type of irrigation does not affect the microclimate. Pandan Wangi can intermittently save more water consumption in local rice cultivation varieties and not cause microclimate change.

1. Introduction
Rice plants (*Oryza sativa* L.) are the main food crop in Indonesia because most Indonesian’s make rice the primary staple food source. Rice enabled them to meet their staple food needs while diversifying their production [1]. The economic, food security and environmental impacts of rice production elicit warranted concerns from scientists, policymakers, and agricultural communities alike [2].

The need for rice every year is increasing, along with the rate of population growth. The rate of population growth in Indonesia is 1.7% per year. In 2025 the population of Indonesia is projected to reach 296 million people with per capita needs of 134 kg or equivalent to 78.3 million tons of dry milled grain. However, the Central Bureau of Statistics noted that rice production in Indonesia decreased in 2019. Rice production only touched 31.31 million tons, decreasing 7.75 percent from 2018 of 33.94 million tons. The decrease in rice production in 2019 was influenced by reducing grain
production in Indonesia, namely, 54.60 million tons of dry milled grain (DMG). This value is 7.76 percent lower than grain production in 2018 of 59.2 million tons of DMG [3]. The system of rice intensification, which improves irrigated rice production, is now being extended or adapted to many other crops: wheat, maize, finger millet, sugarcane, tef, mustard, legumes, vegetables, and even spices [1].

One of the efforts in maintaining and even increasing rice production is the application of intermittent irrigation by the needs of plants. Intermittent irrigation practice is an action to save water needs and maintain microclimate conditions in rice plants. A move from permanent flooding to intermittent irrigation bears short and long-term risks that are not well understood. Still, non-flooded conditions will generally favor rice growth on poor soils with potential for Fe toxicity [4]. The world’s farmers are challenged to produce more food per hectare with less water and fewer agrochemical inputs if possible [1]. When exposed to high temperatures during critical stages, the rice plants can avoid heat. Rice plants maintaining their microclimate temperature below critical levels by efficient transpiration cooling [5]. Total crop biomass is determined mainly by crop photosynthesis and respiration losses, both sensitive to temperature [6].

A large amount of water is required to irrigate an area of rice cropland in conventional irrigation. These higher yields are being attained with reduced field requirements for irrigation water and with much–reduced seed rates [7]. This oxygen is needed for root respiration for rice plants. The model allows for axial diffusion of O₂ and CO₂ through the root and differences with root length and time in cortical porosity, respiration rates in different tissues, and root wall gas permeability [8]. Intermittent irrigation practices are expected to increase oxygen and maintain rice yields while saving water usage. Flooded rice is a water-intensive crop, accounting for approximately 25% of total global annual freshwater usage [2]. The amount of water and nutrients absorbed by plants is strongly influenced by the oxygen content in the soil. Intermittent irrigation can affect soil oxygen and improve the microclimate conditions of rice crops, and soil oxygen content is inversely associated with Root porosity [8]. This research is important to do in the hope that there are some local varieties of rice that do not affect the microclimate and climate change as well as produce higher grain. In the future intermittent irrigation can be applied to the cultivation of local varieties of rice to conserve water. This research aims to test the influence of various kinds of irrigation and varieties on the microclimate change of local rice.

2. Research methods

This research has been conducted at the Research Ground of the Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta in Tamantirto, Kasihan, Bantul, Yogyakarta, Indonesia. The research was conducted from January to May 2020. Tools used, namely soil thermometer, hygrometer digital thermometer LCD HTC-1, lux meter, paralon pipe, digital scale precision 0.005 grams, documentation tools, and planting tools for planting. The ingredients used, namely seeds in Mentik Wangi, Pandan Wangi, and Rojolele, are a superior local variety, manure, Urea, SP-36, and KCL.

The research used experimental methods conducted on land with a factorial design of 3x2 strip-plot compiled in the Randomized Completely Block Design (RCBD). The first factor is rice varieties, consisting of 3 treatments: Mentik Wangi, Pandan Wangi, and Rojolele, while the second factor is the type of irrigation composed of 2 treatments: intermittent and conventional irrigation. Each combination of treatments is repeated three times so that there are 18 research units.

The parameters observed are the microclimate factors of rice. The microclimate factors of rice include air temperature, air relative humidity, soil temperature, and light intensity. The parameters were observed at the time of the maximum vegetative and seed formation phase. Observation of the area of leaves is carried out at maximum vegetative while grain yields per hectare are carried out during harvest. The data is done by analysis with analysis of variance at α= 5% if there is a significantly difference tested further with Duncan Multiple Range Test (DMRT), with a level of α= 5%.
3. Results and discussion

3.1. Air temperature (°C)

The air temperature is obtained from the average air temperature in the morning and afternoon then calculated the average. The analysis of variance of the maximum vegetative phase air temperature above the canopy and below the canopy showed no significant interaction between varieties and irrigation. Intermittent irrigation has no noticeable effect on air temperature, nor does the rice variety affect the air temperature above the canopy and below the canopy when vegetative maximum. The average air temperature in the maximum vegetative phase above the canopy is 34.19°C and below the canopy is 34.35°C (Table 1). Rice can tolerate relatively high temperatures (35/25°C; expressing day/night temperature regime) [9]. During the vegetative stage, high day temperatures can damage the components of leaf photosynthesis. The parts of leaf photosynthesis are mainly photosystem II and membrane properties [9].

Table 1. Air temperature in the maximum vegetative phase.

| Rice Variety     | Type of irrigation | Average  |
|------------------|--------------------|----------|
|                  | Intermittent       | Conventional |         |
| Above the canopy |                    |           |         |
| Mentik Wangi     | 34.30              | 34.14     | 34.22 a |
| Pandan Wangi     | 34.18              | 34.08     | 34.13 a |
| Rojolele Gepyok  | 34.20              | 34.23     | 34.22 a |
| Average          | 34.23 p            | 34.15 p   | (-)     |
| Under the canopy |                    |           |         |
| Mentik Wangi     | 34.30              | 34.28     | 34.29 a |
| Pandan Wangi     | 34.30              | 34.24     | 34.27 a |
| Rojolele Gepyok  | 34.34              | 34.36     | 34.35 a |
| Average          | 34.31 p            | 34.29 p   | (-)     |

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at α = f 5%.

(-) There is no interaction between irrigation and rice variety treatments.

Table 2. Air temperature in the seed formation phase.

| Rice Variety     | Type of irrigation | Average  |
|------------------|--------------------|----------|
|                  | Intermittent       | Conventional |         |
| Top of canopy    |                    |           |         |
| Mentik Wangi     | 33.10              | 33.00     | 33.05 a |
| Pandan Wangi     | 33.46              | 33.32     | 33.39 a |
| Rojolele Gepyok  | 33.38              | 33.14     | 33.26 a |
| Average          | 33.28 p            | 33.19 p   | (-)     |
| Under the canopy |                    |           |         |
| Mentik Wangi     | 33.20              | 33.25     | 33.23 a |
| Pandan Wangi     | 33.64              | 33.61     | 33.63 a |
| Rojolele Gepyok  | 33.57              | 33.30     | 33.43 a |
| Average          | 33.46 p            | 33.40 p   | (-)     |

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at α = f 5%.

(-) There is no interaction between irrigation and rice variety treatments.
The results of the analysis of variance at air temperatures above the canopy and under the canopy of the seed formation phase showed no interaction between varieties and fertilization. Intermittent watering has no noticeable effect on air temperature. Rice varieties also have no discernible impact on the air temperature above and below the heading of rice plants in the seed formation phase. The average air temperature in the seed formation phase above the header is 33.23°C and below the canopy is 34.43°C (Table 2). The effect of SRI practices on the different GHG emissions can vary widely according to soil type, soil moisture, pH, temperature, and other factors, and there are complex interactions among them [7].

3.2. Relative humidity of air (%)
The analysis of variance on the maximum vegetative phase relative humidity of the air above the header and below the heading showed no interaction between irrigation and rice varieties. Intermittent irrigation has no significant effect on relative humidity, nor does the rice variety affect the relative humidity above the header and below the canopy when maximum vegetative phase. The average air relative humidity in the maximum vegetative stage above the canopy and below the canopy is 64.58% and 67.15%, respectively (Table 3). Another study found a significant difference between the average daily relative humidity in the database and observation data that is between 32% to 45% [5].

Table 3. Relative humidity of air in the maximum vegetative phase.

| Rice Variety     | Type of irrigation | Average       |
|------------------|--------------------|---------------|
|                  | Intermittent       | Conventional  |
| Top of canopy    |                    |               |
| Mentik Wangi     | 65.50              | 63.58         | 64.54 a       |
| Pandan Wangi     | 64.75              | 64.58         | 64.67 a       |
| Rojolele Gepyok  | 64.00              | 65.08         | 64.54 a       |
| Average          | 64.75 p            | 64.42 p       | (-)           |
| Under the canopy |                    |               |
| Mentik Wangi     | 67.42              | 66.25         | 66.83 a       |
| Pandan Wangi     | 67.17              | 68.00         | 67.58 a       |
| Rojolele Gepyok  | 66.42              | 67.67         | 67.04 a       |
| Average          | 67.00 p            | 67.31 p       | (-)           |

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at \( \alpha = 5\% \).

\((-)\) There is no interaction between irrigation and rice variety treatments.

The results of the air relative humidity on the seed formation phase that is above the header and below the heading show not significantly interaction between varieties and irrigation. Intermittent watering has no noticeable effect on relative humidity. Rice varieties also have no discernible impact on the relative humidity above and below the heading of rice plants in the seed formation phase. The average humidity in the seed formation phase above the canopy and under the canopy is 68.85% and 69.79%, respectively (Table 4).

The effect of high temperature is closely related to the ambient relative humidity, and hence the level of transpiration cooling is determined by vapor pressure deficit than temperature per se [9]. Lower relative humidity of 60% at 38 °C leads to a higher vapor pressure deficit of 2.65, facilitating the plant to exploit its transpiration cooling ability [9]. The interaction between high temperature and relative humidity, rice cultivation regions in the tropics and sub-tropics can be classified into hot/dry or hot/humid areas [9].
Table 4. Relative humidity of air in the seed formation phase.

| Rice Variety   | Type of irrigation | Average   |
|----------------|--------------------|-----------|
|                | Intermittent       | Conventional |
| Mentik Wangi   | 68.83              | 70.58      | 69.71 a |
| Pandan Wangi   | 66.75              | 67.67      | 67.21 a |
| Rojolele Gepyok| 69.25              | 70.00      | 69.62 a |
| Average        | 68.28 p            | 69.42 p    | (-)     |

Table 1. Light intensity in the maximum vegetative phase (lux).

| Rice Variety   | Type of irrigation | Average   |
|----------------|--------------------|-----------|
|                | Intermittent       | Conventional |
| Mentik Wangi   | 1,124.7            | 1,149.8    | 1,137.2 a |
| Pandan Wangi   | 1,210.0            | 1,179.1    | 1,194.6 a |
| Rojolele Gepyok| 1,250.0            | 1,231.6    | 1,240.8 a |
| Average        | 1,194.9 p          | 1,186.8 p  | (-)     |

The average followed by the same letter in a row or column shows no significant difference based on the variance analysis at α = 5%.

(-) There is no interaction between irrigation and rice variety treatments.

3.3. Light intensity
The analysis of variance on the maximum vegetative phase light intensity above the header and below the header showed no interaction between the rice varieties and irrigation types. Intermittent watering has no noticeable effect on the light intensity, nor does the rice variety affect the light intensity above the canopy and below the canopy when vegetative maximum. The average light intensity in the maximum vegetative phase top of the canopy and under the canopy is 1,190.8 lux and 689.37 lux, respectively (Table 5). The intensity of light in the maximum vegetative phase under the canopy is lower than above the canopy as the plant canopy holds back some light. Another researcher said that by the time the plant was between 15 and 45 days old after transplanting, farmers pulled light boards across the land in several different directions to meet the light needs for the crops [10].

Table 5. Light intensity in the maximum vegetative phase above the header and below the heading.

| Rice Variety   | Type of irrigation | Average   |
|----------------|--------------------|-----------|
|                | Intermittent       | Conventional |
| Mentik Wangi   | 690.44             | 693.78     | 692.11 a |
| Pandan Wangi   | 732.44             | 664.00     | 698.22 a |
| Rojolele Gepyok| 712.00             | 643.56     | 677.78 a |
| Average        | 711.63 p           | 667.11 p   | (-)     |

The average followed by the same letter in a row or column shows no significant difference based on the variance analysis of variance at α = 5%.

(-) There is no interaction between irrigation and rice variety treatments.

The light intensity results in the seed formation phase above the header and below the heading showed no significant interaction between rice varieties and irrigation types. Intermittent watering has
no noticeable effect on light intensity. Rice varieties also have no discernible impact on the light intensity above and below the heading of rice plants in the seed formation phase. The average light intensity in the seed formation phase above the header and below the canopy is 766.03 lux and 519.55 lux (Table 6), respectively. The light intensity in the seed formation phase under the canopy is lower than above the canopy. Low light intensity after flowering decreases rice dry matter [11]. Some of the light is held back by the plant canopy.

3.4. Soil temperature

The results of the soil temperature at the maximum vegetative phase located on the soil surface and 25 cm depth of soil showed no significant interaction between varieties and kinds of irrigation. Intermittent watering has a significant effect on soil temperature. The rice variety no considerable impact on the soil temperature on the soil surface and 25 cm depth of soil when maximum vegetative phase. The average soil temperature with intermittent irrigation in the maximum vegetative stage on the soil surface and 25 cm depth of soil is 32.06°C and 30.36°C, respectively (Table 7). The average

### Table 2. Light intensity in the seed formation phase.

| Rice Variety       | Type of irrigation | Average |       |
|--------------------|--------------------|---------|-------|
|                    | Intermittent       |         |       |
| Mentik Wangi       | 784.67             | 742.67  | 763.67 a |
| Pandan Wangi       | 750.44             | 730.00  | 740.22 a |
| Rojolele Gepyok    | 771.33             | 817.11  | 794.22 a |
| **Average**        | 768.81 p           | 763.26 p| (-)   |
|                    | Conventional       |         |       |

| Rice Variety       | Type of irrigation | Average |       |
|--------------------|--------------------|---------|-------|
| Mentik Wangi       | 568.22             | 490.89  | 529.56 a |
| Pandan Wangi       | 512.00             | 474.45  | 493.22 a |
| Rojolele Gepyok    | 540.22             | 531.56  | 535.89 a |
| **Average**        | 540.15 p           | 498.96 p| (-)   |

The average followed by the same letter in a row or column shows no significant difference based on the variance analysis of variance at α level of 5%.

(-) There is no interaction between irrigation and rice variety treatments.

### Table 7. Soil temperature in the maximum vegetative phase.

| Rice Variety       | Type of irrigation | Average |       |
|--------------------|--------------------|---------|-------|
|                    | Intermittent       |         |       |
| Mentik Wangi       | 30.83              | 30.58   | 30.71 a |
| Pandan Wangi       | 30.75              | 29.83   | 30.29 a |
| Rojolele Gepyok    | 31.58              | 31.08   | 31.33 a |
| **Average**        | 32.06 p            | 30.50 q | (-)   |
|                    | Conventional       |         |       |
| Mentik Wangi       | 30.33              | 29.67   | 30.00 a |
| Pandan Wangi       | 30.42              | 29.42   | 29.92 a |
| Rojolele Gepyok    | 30.33              | 29.67   | 30.00 a |
| **Average**        | 30.36 p            | 29.58 q | (-)   |

The average followed by the same letter in a row or column shows no significant difference based on the analysis of variance at α level of 5%.

(-) There is no interaction between irrigation and rice variety treatments.
soil temperature is higher than conventional irrigation. Other research has found a strong interaction between mechanical impedance and soil temperature, affecting rice root growth [8].

The variety of surface temperature and soil depth analysis in the seed formation phase showed no significant interaction between varieties and irrigation. Intermittent watering has no noticeable effect on soil temperature. Rice varieties also have no discernible impact on the soil temperature on the soil surface and 25 cm depth of rice plants in the seed formation phase. Average soil temperatures with intermittent irrigation on the soil surface and at 25 cm depths in the seed formation phase were 31.50°C and 30.50°C, respectively (Table 8). The average soil temperature is higher than conventional irrigation. In different conditions, namely in high-temperature damage during the development of rice plants, in hotter climates can be avoided by transplanting in puddles to reduce the effect of more desirable dry soil in the root zone experienced in plants on dry land. In such conditions, transplanting would be a better option than direct grafting [9].

### Table 8. Soil temperature in seed formation phase.

| Rice Variety       | Type of irrigation | Average  |
|--------------------|--------------------|----------|
|                    | Intermittent       | Conventional |    |
| Mentik Wangi       | 31.50              | 30.83     | 31.17 a |
| Pandan Wangi       | 31.42              | 30.58     | 31.00 a |
| Rojolele Gepyok    | 31.58              | 31.08     | 31.33 a |
| Average            | 31.50 p            | 30.83 q   | (-)    |
| 25 cm depth of soil|                    |           |        |
| Mentik Wangi       | 30.50              | 29.75     | 30.12 a |
| Pandan Wangi       | 30.50              | 29.58     | 30.04 a |
| Rojolele Gepyok    | 30.50              | 29.58     | 30.04 a |
| Average            | 30.50 p            | 29.64 q   | (-)    |

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at α level of 5%.

(-) There is no interaction between irrigation and rice variety treatments.

### 3.5. Leaf area and grain yield per hectare

### Table 9. Average leave area of rice (cm²).

| Rice Variety       | Type of irrigation | Average  |
|--------------------|--------------------|----------|
|                    | Intermittent       | Conventional |    |
| Mentik Wangi       | 652.50             | 640.60    | 646.51 a |
| Pandan Wangi       | 600.30             | 604.80    | 646.51 a |
| Rojolele Gepyok    | 815.80             | 746.20    | 781.00 a |
| Average            | 689.50 p           | 663.80 p  | (-)    |

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at α level of 5%.

(-) There is no interaction between irrigation and rice variety treatments.

Varieties and irrigation varieties have not significantly interacted, and between varieties and intermittent treatment of water does not affect the area of rice leaves (Table 9). The location of the leaves is influenced by photosynthesis and the formation of chlorophyll. Chlorophyll and the rate of photosynthesis affect the amount or least intensity of sunlight that plants can absorb. Many or at least the intensity of sunlight that plants can drink can be known on the broad index of their leaves. The leaf area index shows the ratio of leaf surface area to the land area shaded by rice plants. Studies in soybean showed that elevated [CO₂] decreased water loss rate and increased leaf area development.
and photosynthetic rate under both well-watered and drought-stressed conditions. There was, however, no significant effect of CO₂ concentration in the response relative to soil water content of normalized leaf gas exchange and leaf area [9]. The extent of the leaves is not constant against time but decreases with the age of the plant. In System of Wheat Intensification (SWI) resulted in better plant architecture with significantly greater root length. Also, more leaf area, higher grain weight, and more filled grains per spike than wheat plants grown with either line-sowing or broadcasting [1].

The results showed no significant interaction between varieties and various irrigation of grain yields per hectare. Varieties give a noticeable influence, while irrigation has no apparent effect on grain yields per hectare. The average grain yield per hectare can be seen in Table 10.

### Table 10. Grain yield per hectare (ton/ha).

| Rice Variety         | Type of irrigation | Average |
|----------------------|--------------------|---------|
|                      | Intermittent       | Conventional |       |
| Mentik Wangi         | 3.08               | 3.83     | 3.46 b |
| Pandan Wangi         | 4.20               | 5.69     | 4.94 a |
| Rojolele Gepyok      | 3.03               | 4.46     | 3.75 b |
| **Average**          | **3.44 a**         | **4.66 a**| **(-)**|

The average followed by the same letter in a row or column shows not significant difference based on the analysis of variance at α = 5%.

(-) There is no interaction between irrigation and rice variety treatments.

Various varieties of rice show a real different influence on grain yield per hectare. Rice varieties Pandan Wangi has a grain yield of 4.94 tons/ha, significantly higher than the Varieties Rojolele and Mentik Wangi (Table 10). The higher result of Pandan Wangi indicates that various varieties have different influences on grain yields per hectare. Each variety has other properties and characteristics as well as different morphology. The generative phase of each rice variety is different concerning the filling period of grains. The SRI also performed poorly under on-farm. Conditions in two sub-districts of Comilla of Bangladesh. Grain yield of SRI practice ranged from 5.92 to 5.98 t ha⁻¹ while BRRI recommended practice ranged from 6.75 to 7.02 t ha⁻¹ [12]. Intermittent and conventional irrigation does not have a significant influence on grain yields per hectare. The results of other studies that in the dry season, the maximum temperature was not related to grain yield (P=0.65). There was a negative relationship between grain yield and minimum temperature (P < 0.01) and a positive relationship between grain yield and radiation (P < 0.05) [6].

### 4. Conclusion

This study concludes: No relationship affects each other between the treatment of irrigation and local rice varieties to air temperature, air humidity, light intensity, and soil temperature. Intermittent irrigation affects the soil's surface temperature and a depth of 25 cm in the maximum vegetative growth phase and at the seed formation phase. The local varieties do not affect the microclimate. Pandan Wangi Rice Varieties produce higher grain, although the three local rice varieties do not influence the microclimate. In the future intermittent irrigation can be applied to the cultivation of local varieties of rice.

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