Adaptation to climate change by using drought tolerant and early maturing rice varieties in Majalengka Regency

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Abstract. One of the efforts to anticipate the impact of climate change on rice is the introduction of new high yielding and early maturing varieties tolerant drought. The aim of this study was to examine the growth performance and potential production of several early maturing and drought tolerant rice varieties in lowland on dry season. The assessment was conducted in Majalengka regency from June to September 2019. Five varieties used were Inpari 39, Cakrabuana, Inpa go 11, Rindang 1, and Luhur 1 with through application of Controlled Aerobic Rice based on Organic matter Technology (CARO). Variables observed including plant height and number of productive tillers, number of grains per panicle, percent of empty grains, and also weight of 1,000 grains. The observations results showed that five tested rice varieties showed good adaptation responses to drought stress with average productivity of around 6 to 7 t ha⁻¹. Cakrabuana was potentially to be developed in dry season under drought stress due to its high yield potential and early maturing (85 days after planting). The early maturing and high yielding varieties in the dry season in lowland can be used as an alternative technology to increase the cropping index (CI) and rice production.

1. Introduction

West Java Province is one of the Indonesian rice production centers. However, West Java had faced decreasing harvested area and rice production, namely from 1,748,620 ha and 10,856,438 t in 2015 [1] to become 1,691,725 ha and 9,539,330 t in 2018 [2]. Based on data obtained from the West Java Department of Food Crops and Horticulture [3], the average CI for rice field in West Java is 2.23 and its value in the rice production centers generally located in the northern region (Subang, Karawang, Indramayu, Cirebon, and Majalengka districts) is 2.10.

The optimization of paddy field for rice cultivation is implemented through intensification efforts to increase production and the planting area through increasing CI in the third planting season. One of the obstacles in optimizing rice field is the limited water availability. Uncertain climate change conditions have caused most of the rice fields to experience water scarcity since the second planting season.

Climate change is one of the threats in Indonesian agricultural sector. Climate change has the potential to reduce harvested area and rice production by 15.8, 11.9, and 11.2% per year in South Sumatra, Malang, and Subang Regencies [4]. The decrease in rain intensity as one of the climate change impacts affects agricultural output. Not only in Indonesia but also in Dharmaputri, India, reducing rainfall intensity is the main reason for the decline in farmers' yields [5].
Majalengka Regency is one of the rice production centers in the northern region of West Java having a rice CI of 2.48 [3]. Intensification of increasing rice CI in the third planting season at the rice fields of Majalengka Regency can be achieved through the application of technological innovations. The adaptation strategy implemented by farmers has affected very positively on crop production [6]. Adaptation strategies to the impacts of climate change on rice fields can be implemented using drought tolerant and early maturing rice varieties. Heretofore, the Indonesian Agency for Agriculture Research and Development (IAARD) through the Indonesian Center for Rice Research (ICRR) has produced a lot of drought tolerant rice varieties, such as inpago, specific rainfed Inpari 38, 39, and 41, and early maturing Cakrabuana and Pajajaran varieties. The research objective was to determine the response of several high yielding, drought tolerant and early maturing rice varieties produced by the IAARD to water stress conditions in the dry season.

2. Materials and methods
A field study was conducted in the third planting season from June to September 2019 at Pasir Village, Palasah District, Majalengka Regency (36 m a.s.l.). The experiment used a randomized block design (RBD) with six replications. The experiment used five new superior varieties produced by the IAARD for lowland (Inpari 39 and Cakrabuana) and upland (Inpago 11, Rindang 1, and Luhur 1) rices The seeds were obtained from ICRR.

The cultivation technology applied in the experiment was Controlled Aerobic Rice based on Organic matter Technology (CARO). CARO technology prioritizes the use of organic matter and water management [7]. The components of the super CARO technology that were applied consist of: 1) the use of new superior varieties that are early maturing, amphibian, and/or drought tolerant, 2) the use of organic matter and biofertilizer, 3) water management, 4) weed control, and 5) the use of agricultural mechanization.

Land preparation was conducted by means of minimum tillage to overturning former rice straw stubble. The organic matter was implemented to improve soil structure through an in situ method, namely utilization of rice straw using decomposers (decomposing microbes). The remaining straw of last season was spreaded evenly on the rice field flooded with 10 cm high water. After that, biodecomposer solution was sprayed evenly on the straw, then the rice field was saturated for 7-10 days, until the straw rot. After that, the soil plowing was conducted for silting the field.

Seed was treated by using 500 g ha⁻¹ (per 25 kg of seed) biofertilizer containing N₂ fixing bacteria, P solvent, and phytohormones. Biofertilizer was applied by stirring it evenly with the seeds having been soaked for 24 hours and drained. Then the seeds were reserved for 24 hours to remove the radicles, henceforth spreaded in the nursery.

Weed control was conducted by imposing of pre-grown herbicides 0 to 4 days after planting (dap). Water management was conducted at the macro and micro level according to the plant nutrient needs. Macrolevel water management was conducted by pumping from water sources (wells and irrigation canals) at intervals according to crop needs. Micro water management was conducted by providing water according to plant needs based on the plant growth phase using AWD (Alternate Wetting and Drying) in the form of hollow pipe that has been placed in field at several points to control the level of water adequacy. Through AWD, time for irrigating plants and the amount of water to be provided could be adjusted to be more efficient. Then the land was flooded 3-5 cm high. If the water condition in the AWD pipe shrinks, then the land needs to be re-watered around 3 days intervals.

Seedlings were planted when the seeds were <21 days old with 1 to 2 seeds per hole. To determine the level of soil fertility and nutrient status, a soil analysis was conducted using the Paddy Soil Test (PUTS) kit. The soil analysis result was used as a recommendation for the dosages of N, P, and K fertilizers to be applied to plants. The results of the PUTS test and fertilization recommendations are presented in Table 1.
Table 1. Soil testing results and fertilizer recommendations dosages in Palasah District in the third planting season of 2019.

| Location | Nutrient Status | Fertilization Recommendations (kg ha⁻¹) |
|----------|-----------------|----------------------------------------|
| Pasir    | High, Low, High | pH (slightly acid) 5-6 170 250          |

Source: PUTS, 2019.

Fertilization was conducted three times, namely at the age of 10, 30, and 45 days after planting (DAP). The first and second fertilizations applied 1/3 urea + 2/3 NPK phonska and 1/3 urea + 1/3 NPK phonska dosages, respectively. At the third fertilization, urea was applied according to the result of the Leaf Color Chart (LCC) observation. Fertilizers were spread evenly among the rice hills. Plant maintenance were weeding and controlling pests and plant diseases according to the attack level in the field.

The plant height (cm) was measured from the soil surface to the tip of the highest leaf or panicle and recorded at harvest time. The number of vegetative tillers per hill was calculated at 45 DAP and the number of productive tillers (which emitted panicles) was recorded at the time before harvest (90 DAP). The flowering time was recorded when 50% of the population in the plot had flowered is counted in days after sowing (das). The ripening time was recorded when the plants were up to 90% of grain turns yellow is counted in dap. The yield (t ha⁻¹) of harvested dry grain was obtained by harvesting all panicles in one plot with a minimum area of 10 m². Panicle length (cm) was recorded by measuring the length of the panicle neck until the last grain at the end of panicle. The number of grains per panicle (grain) was counted the whole number of filled and unfilled grains from 3 panicles in the sample. Percentage of unfilled grain per panicle was also recorded. The weight of 1,000 grains (g) was weighed from 1,000 filled grains.

A one-way analysis of variance (ANOVA) was conducted (α=0.05) using SAS v. 9.1 to analyze the observation data. Duncan post hoc test was performed following ANOVA to identify the treatments significantly different based on the ANOVA test.

3. Results and discussion

3.1. Rainfall

The experiment was conducted during the third planting season (June to October 2019), when the rainfall was at its lowest amount. Based on the graph of rainfall and rainy days (Figure 1), there was no rainy days since June to October. These climatic conditions affected rice cultivation techniques applied in this study, especially water resources management.

The application of the CARO technology components includes the management of water resources for irrigating rice fields. The irrigation system usually conducted by farmers during the dry season in rice fields is by pumping water from channels or wells periodically, twice a week. However, in this study, the amount of water supplied to rice fields was controlled using AWD until the soil was saturated.
3.2. Plant height and number of tillers

The average of plant height at the 90 DAP varied between 71.8-142.6 cm which was significantly higher (142.6 cm) on Inpago 11 than those in Inpari 39 (71.8 cm), Cakrabuana (91.5 cm), Rindang 1 (91.4 cm), and Luhur 1 (117.5 cm) varieties. Genetically, the heights of the five rice varieties were different and the varieties were divided into two groups, namely upland (Inpago 11, rindang 1, and Luhur 1) and lowland (Cakrabuana and Inpari 39) rice varieties, respectively. The altitude also determines the climate, including temperature, sunlight, humidity, and wind, affecting the plant growth process. The Standard Evaluation System for Rice classifies plant heights of lowland and upland rices into three categories [8], namely semidwarf (<110 and <90 cm), intermediate (110–130 and 90–125 cm), and tall (> 130 and >125 cm), respectively.

Table 2. Agronomic Character of Rice Varieties.

| No | Variety    | Plant Height (cm) | Number of Vegetative Tiller | Number of Productive Tiller |
|----|------------|-------------------|----------------------------|-----------------------------|
| 1  | Inpari 39  | 71.8 d            | 32.7 a                      | 32.6 a                      |
| 2  | Cakrabuana | 91.5 c            | 34.2 a                      | 26.5 b                      |
| 3  | Inpago 11  | 142.6 a           | 29.0 b                      | 23.2 b                      |
| 4  | Rindang 1  | 91.4 c            | 26.9 b                      | 23.2 b                      |
| 5  | Luhur 1    | 117.5 b           | 23.1 c                      | 17.2 c                      |
|    | CV (%)     | 4.56              | 6.58                        | 16.76                       |

Note: Values with similar superscript letters within a column are not significantly different at P(0.05).

Generally, the five rice varieties tested were adaptive to dry season environmental conditions as indicated by relatively satisfying vegetative growth. The response of plants to environmental or water stress depends on the ability of their roots to absorb water under such soil conditions. The response of roots to water stress is highly dependent on the crop genotype, and period and intensity of stresses [9].

The highest numbers of tillers in the vegetative phase were shown by Inpari 39 and Cakrabuana varieties of 32.7 and 34.2 tillers per hill, respectively, however, the Luhur 1 variety produced the least number, namely 23.1 tillers per hill. Meanwhile, Inpari 39 and Cakrabuana varieties significantly had a greater number of productive tillers being 32.6 and 26.5 tillers, respectively. In general, genetically upland rice varieties have fewer tillers than those in lowland. The number of productive tillers will affect the yield because they determine the number of panicles and grain produced per plant hill. Better plant
adaptation to drought stress, especially in the reproductive tiller phase, greatly affects on the percentage of panicle emergence. The impact of drought stress affects the growth of rice, especially in the flowering phase. Drought stress at flowering stage has a strong influence on rice physiological traits and yield [10]. Drought stress considerably influenced the number of rice panicle hill\(^1\). Results of other study stated that among the different levels of drought stresses, severe drought stress exhibits the lowest number of panicle hill\(^1\) [11].

3.3. Flowering time, ripening time, dan panicle length
Rice lines that reach 50% population at flowering phase earlier have the potential to harvest early (early maturing) [12]. Observation on the time of 50% population at flowering phase at the five varieties tested, the Cakrabuana variety had a 50% population at flowering phase significantly faster 56 day after sowing (das), while the Inpari 39 variety was the slowest (70 das). Flowering time can also be influenced by climatic factors. In dry conditions, rice will generally flower faster due to the relatively high temperature conditions as high temperature conditions accelerate plant growth and panicle initiation [13].

The criteria for the age of rice plants are early maturing (100 to 115 das), moderate (116 to 125 das), and late maturing (126 to 150 das) [14]. The ripening time of all tested varieties was <100 das or early maturing. However, the analysis result (Table 3) shown the ripening time of the Cakrabuana variety is significantly faster (85 das) than other varieties. This showed that the Cakrabuana variety was the earliest maturing. Early maturing varieties can be used to overcome the short rainy periods due to climate change, as well as to increase the harvest index [15]. In addition, the introduction of early maturing rice varieties will make the utilize of limited irrigation water more efficient, especially in supplementary irrigation through pumping.

| No | Variety | Flowering Time 50% (das) | Ripening Time (das) | Length of Panicle (cm) |
|----|---------|--------------------------|--------------------|-----------------------|
| 1  | Inpari 39 | 70.17 a | 94.00 a | 24.42 c |
| 2  | Cakrabuana | 56.00 e | 85.00 b | 26.30 b |
| 3  | Inpago 11 | 59.17 c | 94.00 a | 29.21 a |
| 4  | Rindang 1 | 60.83 b | 94.00 a | 25.60 b |
| 5  | Luhur 1 | 58.00 d | 94.00 a | 23.52 c |
| CV | (%) | 1.52 | 0.0 | 3.03 |

Note: Values with similar superscript letters within a column are not significantly different at P(0.05)

The length of panicle can be used as a variable that determines the high and low productivity of rice, as it affects the number of filled grains per panicle. Panicle length classification is divided into short (20 cm), medium (21 to 30 cm), and long (>30 cm) [16]. The results of this study showed that all the varieties tested had medium panicle length criteria. Inpago 11 varieties had significantly longer panicle length (29.21 cm) than other varieties, while Inpari 39 and Luhur 1 varieties had the shortest panicle length 24.42 cm and 23.52 cm, respectively.

3.4. Yield dan yield component
The rice productivity tested ranged from 6 to7 t ha\(^{-1}\) of harvested dry grain, the Cakrabuana variety produced significantly higher rice productivity (7.15 t ha\(^{-1}\)) than other varieties. Grain quality is important factor in rice production since it will affect rice yields. Good grain quality is determined by the number of filled grain and unfilled grains per panicle. The observation in the field showed that two varieties had significantly higher grain contents per panicle, namely Inpago 11 (192.80 grains) and Luhur 1 (196.12 grains).

Dry conditions will affect the decline in rice production. Rice yields obtained under drought stress were significantly reduced by 23.2% to 24.0% [10]. Reduced grain yield under lowered soil moisture
levels might be due to inhibition of photosynthesis and less translocation of assimilates towards reproductive parts due to soil moisture stress [11]. However, during the dry season, the quality of rice is generally better than in the rainy season, due to the sun intensity which full throughout the season and the relatively low attack of pests and diseases. Furthermore, full solar radiation throughout the dry season has a positive influence on the photosynthetic process of plants. At full sun intensity, the yield components (panicle length, number of panicles per hill, number of grains per hill and weight of 1,000 grains) were significantly increased and correlated positively with yields [17].

According to the data in Table 4, the highest percentage of unfilled rice grain was Rindang 1 (26.40%). Meanwhile, the lowest percentage of unfilled rice grain was Inpari 39 (15.67%). The large percentage of unfilled rice grain affects the quantity of grain per panicle and determines the magnitude of yield. Apart from the percentage of unfilled grain, the weight of the seeds also affects the yield. Inpari 39 had a low percentage of unfilled rice grain, but the seed weight was smaller (24.77 g) than Cakrabuana (27.45 g), therefore the Inpari 39 yield was lower than Cakrabuana.

| No | Variety     | Yield (t ha⁻¹) | Number of filled grains per panicle | Number of unfilled grains per panicle | % unfilled grains per panicle | Weight of 1000 grains (g) |
|----|-------------|---------------|-------------------------------------|---------------------------------------|-----------------------------|--------------------------|
| 1  | Inpari 39   | 6.47 b        | 124.97 b                            | 23.42 c                               | 15.67 c                     | 24.77 d                  |
| 2  | Cakrabuana  | 7.15 a        | 117.07 b                            | 35.27 b                               | 23.33 ab                    | 27.45 b                  |
| 3  | Inpari 11   | 6.55 ab       | 192.80 a                            | 60.47 a                               | 23.73 ab                    | 23.02 e                  |
| 4  | Rindang 1   | 6.07 b        | 117.18 b                            | 41.05 b                               | 26.40 a                     | 29.58 a                  |
| 5  | Luhur 1     | 6.62 ab       | 196.12 a                            | 40.30 b                               | 17.83 bc                    | 25.63 c                  |
|    | CV (%)      | 7.56          | 13.08                               | 18.83                                 | 16.73                       | 1.498                    |

Note: Values with similar superscript letters within a column are not significantly different at P(0.05).

Rice is highly susceptible to water stress during the reproductive stage, leading to significant reduction in grain yield [18, 19]. The degree of yield loss depends on the growth stage, duration, and the severity of drought stress [20, 21]. The adaptability of a variety to drought stress can be seen from its initial phase to harvest. Because the plants response at each growth phase will be different. Thus, better recovery capability is important to keep relatively high grain production under drought stress conditions [10].

4. Conclusions
Five rice varieties tested showed good adaptation responses to drought stress. The average productivity of those varieties is around 6 to 7 t ha⁻¹. Cakrabuana variety is potential to be developed in dry season on drought stress due to its high potential yield and early maturing (85 DAP). The use of early maturing and high yielding varieties in the dry season in lowland can be used as an alternative technology to increase CI and rice production.

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