Rice cultivation on dry land during dry season supported by deep well irrigation and soil amelioration

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Abstract. Dryland has a great potential regardless of limitations. Increasing rice productivity can be done by water and land management on the dryland especially on dry season. This study aimed to determine rice cultivation in dry land during the dry season which is supported by deep well irrigation and soil amelioration with organic fertilizers and rice husk charcoal. The research was conducted on dry land at Logandeng, Playen, Gunung Kidul, Special Region of Yogyakarta Indonesia during the 2019 dry season, July to November. Water requirement was fulfilled from deep well irrigation. Soil quality was improved through amelioration with organic fertilizers and rice husk charcoal, with the treatments without amelioration (TA), amelioration with organic fertilizer 3 ton ha⁻¹ (AB), amelioration with organic fertilizer 3 ton ha⁻¹ plus rice husk charcoal 1 ton ha⁻¹ (ABS) and amelioration with organic fertilizer 3 ton ha⁻¹ plus rice husk charcoal 1 ton ha⁻¹ and mulch of rice husk charcoal 0.5 ton ha⁻¹ (ABSM). This research used a randomized completely block design, with 4 treatments and 5 replications. The results showed by 5 cm of flooding was reached the zero level in 8 hours and the water depth reached 20 cm for the next 16 hours. Supplementary irrigation every two days, with a flooding of 5-10 cm, was sufficient for rice cultivation during the dry season. ABS treatment can increase the yield component such as dry grain yield by 7.10 ton ha⁻¹, dry straw by 5.98 ton ha⁻¹, and dry root by 2.76 ton ha⁻¹ and carbon absorption from grain by 3.81 ton ha⁻¹, straw by 2.68 ton ha⁻¹ and root by 1.18 ton ha⁻¹ (p<0.05 ; n=20). ABS was decreased soil Eh (p<0.05; n=20), and increased soil organic carbon and cation exchange capacity (p<0.05; n=15). ABS was the best ameliorant for rice cultivation on dry land during dry season.

1. Introduction
Rice is one of the most primary food and the main sector in Indonesia. As yet, rice cultivation are considerately full filled on lowland, both irrigated and rainfed condition. Paddy fields actually decrease and convert into industrial, residential and other non-agricultural areas [1]. Indonesia's rice harvested area was 16.11 million ha on 2018 and has decreasing by 33.7% or around 10.68 million ha on 2019 [2]. Just relying on lowland rice cultivation cannot realize increased rice productivity. Increasing rice productivity can be done by optimizing dry land.

Dry land has a great potential to increase food productivity [3]. Asnah et al. [4] suggested dry land has a chance to cultivated, including rice [5]. Indonesia's dry land area is 144.5 million ha (76.2% of the total land area) including forest areas [6], with a wet and dry climate [7]. Dry land should take a part the important role in supporting food self-sufficiency [8].
The main problem of dry land is lack of water [9] [10], low nutrients and low organic matter content [11, 12, 13, 14, 15]. In general, dry land has low productivity [16].

Increasing the productivity of dry land can be supported by groundwater irrigation [17]. Groundwater withdrawal does not exceed aquifer ability [18, 19]. Groundwater is used together with surface water and reused water [20]. Paddy water infiltration during irrigation contributes to groundwater replenishment, significantly [21].

Soil organic carbon greatly determines the quality of dry land [15]. Organic carbon determines the physical, chemical and biological properties of soil, as well as plant growth [14], although its proportion is small in soil [22]. Organic fertilizers from livestock are widely used as ameliorants, a source of nutrients and carbon [23].

Biochar is resistant to the decomposition process, has a higher surface area so that it is able to absorb ions better [24]. Biochar ameliorant significantly improves all indicators of soil quality [25], health and soil status [26]. Biochar is a soil ameliorant that is beneficial for plants [27].

This study aimed to determine rice cultivation in dry land during the dry season which is supported by deep well irrigation and soil amelioration with organic fertilizers and rice husk charcoal.

2. Material and methods

2.1 Experimental site condition

This study was conducted at Logandeng, Playen, Gunung Kidul, Special Region of Yogyakarta, Indonesia on July to November 2019 during dry season. The study field had coordinates of 7°56'0"N, 110°34'43"E, and a height of 212 m above sea level. The existing cropping pattern are rice/corn - corn/peanut - corn/peanuts/vegetables. In this study, rice was planted in the third growing season to replace another plants cultivation such corn, vegetables, or peanuts. The average of annual rainfall is 1,852 mm, with consecutively seasons are 5 months of wet and 6 months of dry season. Soil and climatic properties can be seen in Table 1.

| Table 1. Soil and climate properties |
|--------------------------------------|
| pH | TOC (%) | TN (%) | CEC (c mol(+) kg(-1)) | pF 2.54 | pF 4.20 | permeability (cm.hr(-1)) | P (mm) | T (°C) |
|----|---------|--------|------------------------|--------|---------|--------------------------|--------|-------|
| Top soil | 6.17 | 1.12 | 0.21 | 26.93 | 33.54 | 17.10 | 2.49 | 1,852 | 26.5 |

Treatments and experimental design

On dry land, plant growth and plant productivity are limited by water availability and soil fertility, so as the solution are providing the water and improving soil properties. This study was used deep wells for water supply, with irrigation every 3 days. Organic fertilizer and husk charcoal treatments were used to find the best ameliorant, to improve soil properties. This research used a randomized completely block design, with 4 treatments and 5 replications. The treatment were without amelioration (TA), amelioration with organic fertilizer 3 ton ha(-1) (AB), amelioration with organic fertilizer 3 ton ha(-1) plus rice husk charcoal 1 ton ha(-1) (ABS) and amelioration with organic fertilizer 3 ton ha(-1) plus rice husk charcoal 1 ton ha(-1) and mulch of rice husk charcoal 0.5 ton ha(-1) (ABSM). AB treatment was TA plus 3 ton ha(-1) of organic fertilizer, ABS was AB plus 1 ton ha(-1) of rice husk charcoal. ABSM was ABS plus 0.5 ton ha(-1) rice husk charcoal mulch. Combination of treatment to determine the role of ameliorant for improving soil quality.

2.2 Cultivation details

The tillage was carried out twice before planting. The first and second tillage was a week difference. Organic matter and rice husk charcoal given during the first tillage by hand tractor. A rice variety, Inpari-19, was planted using jajar legowo system of 2:1 and transplanted 4−5 seedlings of 15 days after sowing (DAS).
The experiment fields were supplied by 200 kg ha\(^{-1}\) of 46% N and 300 kg ha\(^{-1}\) of 15:15:15 NPK. The fertilizer was given three times with 1/3 of fertilizer was applied as the basic fertilizer, 2/3 fertilizer was provided on 10 days after transplanting (DAT) and the last 1/3rd at tillering initiation stage or 25 DAT. Liquid fertilizer was sprayed at 10, 20, 30, and 40 DAT.

The weeds properly controlled at 10, 20, 30 DAT and if still needed. The pest and diseases also controlled. Irrigation was carried out from deep well every two days and irrigated until 76 DAT with the water level around 5-10 cm. The water content was not less than pF 4.20 of permanent wilting point. Rice was harvested at 103 DAT.

2.3 Sampling and measurement of parameters
Water level was carried out at 5 cm and measured per hour for 24 hours. pH and Eh are measured once per two weeks during the irrigation stage. Soil samples were taken to determine soil properties such as pH, total organic carbon, total nitrogen, cation exchange capacity, pF and soil permeability [28]. Incubation of soil plus ameliorant were used to determine the organic carbon content and cation exchange capacity at the initial and TA, AB, ABS, and ABSM at the end, with three replication. Harvested dry grain, straw and roots were taken after harvest drying. The carbon content of grain, straw and roots is determined based on the carbon content in the tissue.

2.4 Statistical Analysis
The observed data were analysed using the IBM SPSS 25 64-bit (PC/Windows 8-10) to determine the variance of the various parameters. The significant treatments was determined by the F test and Duncan Multiple Range Test (DMRT) to find the interaction effect of the treatments to estimate Least Significant Difference (LSD) at <0.05 level of significance [29].

3. Results and discussion
3.1 Water availability
This study utilizes groundwater from deep wells. There are various factors that impact the height of the groundwater levels such as droughts, seasonal variations in rainfall, and pumping affect the height of the ground water levels [30]. The depth of the well is 120 meters, the water flow rate was 25 liters per second. Deep well irrigation for paddy does not disturb other crops.

Study on water infiltration in a 5 cm flooding as the basis for determining the need for irrigation water (Figure 1). Infiltration was calculated based on the water level.

![Figure 1](image)

**Figure 1.** Water levels of the experiment field by flooding 5 cm water each 24 hours

This study showed that 5 cm of flooding was reached the 0 level of water after 8 hours and the water depth level reached 20 cm after the next 16 hours. During this study, there was no rain which affected the water levels. Irrigation every two days with a height of 5-10 meters was the optimum condition as observed. The water content was not less than pF 4.20 of permanent wilting point. Irrigation from deep well was sufficient to support rice cultivation in the dry season.
3.2 Yield components and carbon absorption

Table 2 presents the parameters such as yield, straw, root, and carbon content in varied treatment. The ABS treatment resulted in dry grain 7.12 ton ha\(^{-1}\), dry straw 5.98 ton ha\(^{-1}\) and dry root 2.77 ton ha\(^{-1}\), significantly different from TA and AB, but not from ABSM. Carbon absorption in ABS treatment was 3.82 ton ha\(^{-1}\) for grain, 2.68 ton ha\(^{-1}\) for straw and 1.19 ton ha\(^{-1}\) for root, higher than TA and AB, and it is no different from ABSM (p <0.05; n=20).

| Treatment | Grain (ton ha\(^{-1}\)) | Straw (ton ha\(^{-1}\)) | Root (ton ha\(^{-1}\)) | Grain Carbon (ton ha\(^{-1}\)) | Straw Carbon (ton ha\(^{-1}\)) | Root Carbon (ton ha\(^{-1}\)) |
|-----------|------------------------|-------------------------|----------------------|-------------------------------|-----------------------------|-----------------------------|
| TA        | 5.99±0.05a              | 4.47±0.06a              | 1.73±0.15a           | 3.22±0.03a                    | 2.01±0.03a                  | 0.74±0.06a                  |
| AB        | 6.69±0.07b              | 5.24±0.17b              | 2.25±0.13b           | 3.59±0.04b                    | 2.35±0.08b                  | 0.97±0.06b                  |
| ABS       | 7.12±0.15c              | 5.98±0.21c              | 2.77±0.04c           | 3.82±0.08c                    | 2.68±0.09c                  | 1.19±0.02c                  |
| ABSM      | 7.23±0.10c              | 6.03±0.16c              | 2.80±0.10c           | 3.88±0.05c                    | 2.71±0.07c                  | 1.20±0.04c                  |

Note: The numbers that followed by the same letter in the same column show no significantly different in the DMRT of 5%. Data source: primary research

This results indicated that organic fertilizer 3 ton ha\(^{-1}\) plus rice husk charcoal 1 ton ha\(^{-1}\) (ABS) can increase the yield component and carbon absorption on rice cultivation in the dry land during dry season. Organic fertilizer improves soil properties [14], plant growth and yield [22]. Rice Husk Charcoal (RHC) has positive impact on the parameters. Increasing the yield parameters can be due to the availability of nutrient since the increased water holding capacity of soil [31, 32], and soil fertility [33]. Sohi [34] stated that C and the other major nutrient in soil could be enriched by RHC. Knoblauch et al. [35] presented a higher carbon value of 43% in RHC. Providing organic fertilizer and RHC are advantageous for rice cultivation in dry land which is water and nutrients are lacked. The result in accordance with the recent study by [36, 37, 38] that the grain yield improved by the providing of RHC. Mulching is one of water-saving technique, and generally use in many crops, additionally to reduce soil evaporation and also soil water storage capacity [39], but not effective in this study.

3.3 Soil properties development

3.3.1 Soil pH and Eh

pH and soil redox potential (Eh) was observed and analysed to determine the soil properties development by providing various treatments. Flooding raised soil pH (Figure 2), but did not differ between treatments. Increasing pH has a positive impact. [40, 15] reported that neutral pH made the nutrients more available adsorbed by the plant that take an impact to plant growth and yield.

Figure 2. The average of soil pH and Eh on the various treatments
Soil Eh decreased due to flooding (Figure 2). On the 18th, 32nd, 46th, 60th and 74th days after transplanting, Eh in ABS was lower than TA and AB, but not different with ABSM. It is also for the Eh average (p<0.05; n=20). Organic carbon application to flooded soil accelerates the Eh decline [15], as in the treatment of AB, ABS dan ABSM. The biochar could enhance soil water-holding capacity and water stable aggregate [25, 41], potentially decreasing soil Eh, as in ABS and ABSM.

3.3.2 Soil organic carbon and Cation Exchange Capacity
Soil organic carbon content in ABS treatment was higher than TA, AB and initial soil, but not different from ABSM (p<0.05; n=15) (Figure 3). Organic fertilizer application of 3 ton ha$^{-1}$ was not sufficient to increase the soil organic carbon content, because the rapid loss of the soil organic carbon in dry land, which according [27] indicated a more active microbial process. ABS treatment, with the addition of rice husk charcoal by 1 ton ha$^{-1}$, was able to increase soil organic carbon content. Rice husk charcoal is more resistant to decomposition, so it last longer in the soil, like a statement Zimmerman et al. [42] Mulch of RHC by 0.5 ton ha$^{-1}$ is not effective to increase soil organic carbon content.

![Figure 3. The Organic carbon and cation exchange capacity on the various treatments](image)

The cation exchange capacity in ABS treatment was higher than TA, AB and initial soil, but not different from ABSM (p<0.05; n=15) (Figure 3), the same as in soil organic carbon. Organic fertilizers determine the soil cation exchange capacity [14], as well as RHC [25]. RHC also increase the soil condition by improving soil chemical properties [37, 43]. Organic carbon determines the cation exchange capacity. A positive correlation (p<0.05; n=5) occurs between soil organic carbon and soil cation exchange capacity.

4. Conclusions
Supplementary irrigation from deep well every two days, with a flooding of 5-10 cm, was sufficient for rice cultivation during the dry season. The effectiveness of water can be increased through soil amelioration. Ameliorant with organic fertilizer 3 ton ha$^{-1}$ plus RHC 1 ton ha$^{-1}$ (ABS) was the best for rice cultivation on dry land during dry season. ABS resulted in dry grain 7.12 ton ha$^{-1}$, dry straw 5.98 ton ha$^{-1}$ and dry root 2.77 ton ha$^{-1}$. Carbon absorption by ABS was 3.82 ton ha$^{-1}$ for grain, 2.68 ton ha$^{-1}$ for straw and 1.19 ton ha$^{-1}$ for root. ABS was increased soil organic carbon and cation exchange capacity, but decreased soil Eh.

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