Application of organic amendments and PGPR on Salibu Rice yield for drought adaptation

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Abstract. Drought is one of the climate change phenomena that has a profound impact on agricultural crops. Various adaptation strategies are used to deal with the impacts of climate change, one of which is the ratoon system of rice cultivation. This study aims to examine the effects of providing a combination of organic amendment and the application of PGPR on soil characteristics, growth, and yield of salibu ratoon system in the rainfed dry land. The research was conducted in Wonosari Village, Gondangrejo, Karanganyar, Central Java. This research used a complete randomized block design with three replications consisting of 2 factors. The first factor is the organic amendment, which is without the addition of organic matter (C1), compost (C2), and rice husk charcoal (C3). The second factor is the PGPR treatment, which is non-inoculated PGPR (P1) and inoculated PGPR (P2). Data analysis used ANOVA level of 5% followed by Duncan’s test. The results showed that the addition of organic matter and the inoculation of PGPR affected the variable root length, yield, and biomass. The addition of organic matter and PGPR can increase crop yields and plant resistance to drought stress by maintaining soil moisture and root elongation mechanisms. Based on the research results, the addition of rice husk charcoal and PGPR inoculation is the best combination for ratoon rice cultivation in the rainfed dry land.

1. Introduction
Drought is a natural phenomenon related to climate, especially rainfall that affects agricultural, environmental, and socio-economic conditions [1]. Drought is one of the phenomena of climate change that has a profound impact on all areas of activity including agriculture which reduces agricultural production, especially food, especially on rainfed or dry land [2]. Gupta [3] stated that drought resulted in more loss of agricultural crops compared to pathogens. The availability of groundwater is a major limiting factor in agricultural land due to its direct effect on agricultural output due to global climate change [4]. The photosynthetic process of plants will be disrupted when the water supply in the soil reaches an absolute pressure that prevents plants from absorbing it [5]. The availability of water in rainfed land is one of the considerations for rice cultivation in the dry season [6]. The problem with maize cultivation in rainfed land is water deficit but it can be overcome with
proper land management, one of which is the addition of organic matter [7]. Ratoon rice cultivation is an effort to increase rice production per unit area of land [8] as well as being a solution for water-efficient rice cultivation. The advantages of ratoon cultivation are lower production costs (without initial tillage and replanting), less fertilizer required, shorter harvest life, and yields that can provide additional production and increase productivity per unit of the same land area [8]. Ratoon rice application can be a viable choice to achieve high annual productivity, a large balance of energy and profit while reducing environmental impact [9]. According to Fitri [10] with the modification of ratoon technology, salibu can be harvested up to 3.5–4 times a year with a yield equivalent to the main harvest. However, the ratoon system is rarely used by farmers because generally, the rice yields obtained are lower [8]. So it is necessary to improve cultivation techniques while increasing plant resistance to drought.

One of the efforts to overcome drought in agricultural land, especially ratoon salibu rice cultivation is by maintaining soil moisture. Organic matter plays an important role in improving soil physical properties, one of which is soil moisture [11]. The results of the study [12] show that organic fertilizers are able to maintain soil moisture. The application of organic matter significantly increases the soil water content and decreases the C/N ratio of the soil [13]. Drought stress affects the morphological and physiological characters of plants which has a negative impact on fresh weight, relative moisture content and inhibits the absorption of nutrients by plants. PGPR (Plant Growth Promoting Rhizobacteria) can reduce the impact of drought stress on beans [14] and soybeans [15]. Based on previous research, organic amendments such as manure, PGPR, compost, and biochar effectively improve soil physical properties and nutrient availability [16–21].

From existing studies, there has been no research on the role of organic matter and PGPR in ratoon rice cultivation, especially in rainfed land. So this study aims to examine the effect of providing a combination of organic matter and the application of PGPR on soil characteristics, growth, and yield of salibu ratoon system in the rainfed dry land.

2. Materials and method

2.1 Materials
This research was conducted in September 2020 - March 2021 in Wonosari Village, Gondangrejo, Karanganyar, Central Java. The geographical location is located at 110°56′51″ East Longitude and 07°37′48″ South Latitude with an altitude of 191 meters above sea level. Laboratory analyzies were carried out at the UNS physics, and soil chemistry laboratories and the Gifu-UNS Integrated Laboratory. The materials used were composite soil from the research location, rice seeds (Var. Situ Bagendit), compost, rice husk charcoal, and PGPR. The tools used are a set of AWS sensors (rain gauge type ECRN-100), temperature, humidity, air pressure (ATMOS 14 Humidity / Temp / Barometer) sensors, Decagon Em5b Soil Moisture Probe and Data Logger, soil drill, analytical scales, oven, and others.

2.2 Methods
The research design used was a completely randomized block design with 3 replications (blocks) consisting of 2 factors. The first factor is organic amendment consisting of 3 levels, without the organic amendment (C1), compost (C2), and rice husk charcoal (C3). The second factor is the PGPR treatment consisting of 2 levels, non-inoculated PGPR (P1) and inoculated PGPR (P2). The environmental design is based on the direction of the slope or fertility levels of the land. As for the sampling of soil by purposive sampling.

This study uses experimental research methods that aim to find the influence of the relationship or correlation of organic amendment and PGPR, and the availability of groundwater on plant parameters. Data analysis used correlation analysis and analysis of variance (ANOVA), if it was significantly different, then continued with the Duncan test at 5% level.
Observation of root length was measured from the base of the root to the tip of the root with a ruler. Root length was measured at the end of the study. Harvest observations are carried out by weighing the dry grain weight and expressed in units of tonnes/ha. Plant biomass observations were carried out by weighing fresh rice plants that had been ovenized at 70°C for 48 hours and weighed to determine the dry weight.

3. Results and discussions

The results of the ANOVA and correlation of the treatment of organic amendment and PGPR on the analysis variables can be seen in Tables 1 and 2.

Table 1. ANOVA treatment of the ratoon variable.

| Treatment       | Ratoon root length | Ratoon yield | Ratoon biomass |
|-----------------|--------------------|--------------|----------------|
| Organic matter  | ns                 | ns           | ns             |
| PGPR            | ns                 | ns           | ns             |
| OM vs PGPR      | * (Sig. 0.022)     | ns           | ns             |

Table 2. Correlation between parameters.

| Parameters     | Ratoon yield       | Ratoon biomass |
|----------------|--------------------|----------------|
| Root length    | * (Sig. 0.016)     | ** (Sig. 0.002) |
| Ratoon yield   | -                  | ** (Sig. 0.001) |

Note: ns (non significant), * (significant at 0.05 level), ** (significant at 0.01 level)

Based on Table 1, the interaction of organic matter and PGPR has a significant effect on the root length of ratoon rice. Meanwhile, Table 2 shows that root length has a positive correlation with yield and biomass in ratoon. Yields have a positive correlation with ratoon biomass. This shows that the longer roots will increase the yield and biomass of ratoon rice. Root length is a plant component related to the process of absorbing water and nutrients from the soil. The distribution of plant roots that are longer and broader results in a wider water and nutrient absorption area so that it is more optimal for plant productivity [22]. The interactions showed that the organic amendment and PGPR can increase root length. Organic matter acts as a provider of nutrients and binds better groundwater, while PGPR is a biological agent that has mutualism symbiosis with plants, especially in root areas to spur plant growth. Several types of biological agents can fix nitrogen from free air, dissolve P and K elements in the soil and other nutrients so that they can indirectly provide nutrients for plants. In addition, PGPR can stimulate plant growth by producing growth hormones such as auxins and cytokinins. Shaharoona et al. [22] stated that the absorption of nutrients in plants is highly dependent on root growth and the availability of nutrients around the roots. Better root growth is an indicator for healthy plant growth [22]. So that it can increase ratoon rice yields.

3.1. Root length

The role of rice roots in the absorption of water and nutrients during growth affects the photosynthetic process in producing grain or crop yields and it is very important in rainfed land because soil water absorption depends on the ability of plant roots to penetrate deeper soil layers. Root growth is influenced by environmental conditions, texture, soil type, water, air, and soil management methods [23]. Based on the results analysis, the combination of treatments between organic amendment and PGPR showed a significant interaction with root length. The results of root length can be seen in Figures 1 and 2.
Figure 1. Effect of treatment combinations on the root length of ratoon rice; C1P1= without OM, non inoculated PGPR; C1P2= without OM, inoculated PGPR; C2P1= compost, non inoculated PGPR; C2P2= compost, inoculated PGPR; C3P1= rice husk charcoal, non inoculated PGPR; C3P2= rice husk charcoal, inoculated PGPR; (means followed by the same letter differ significantly at alpha 0.05).

Figure 2. The length of rice roots by giving OM (a) and PGPR (b); C1= without giving OM; C2= compost; C3= rice husk charcoal; P1= non inoculated PGPR; P2= inoculated PGPR; error bar represents standard error.

Based on Figures 1 and 2, giving OM and PGPR inoculation was able to increase the root length of ratoon rice compared to control (without giving organic matter and PGPR). The best treatment was given the rice husk charcoal and PGPR inoculation which resulted in the highest root length (15.03 cm). Giving rice husk charcoal to the treatment causes the soil structure to become more loose and easy to penetrate by plant roots. Meanwhile, PGPR inoculation was able to increase root elongation. This is following the results of research by [22], that the addition of PGPR was able to increase root length growth in wheat plants. The PGPR inoculated rice showed better growth, increased root length, and plant dry weight [24]. PGPR was able to increase the root length and root weight of maize compared to controls [25]. The results of the research by [26] stated that by inoculating mycorrhizal and rhizobium separately or in combination it was significantly able to increase the root length of Indigofera tinctoria compared to control (without inoculation).
Figure 3. Values of soil bulk density; C1 = without giving OM; C2 = compost; C3 = rice husk charcoal.

Based on Figure 3, soil treated with rice husk charcoal gives a lower bulk density (BD) value (1.44 g/cm$^3$) compared to control (1.50 g/cm$^3$) and compost treatment (1.49 g/cm$^3$). BD value shows the density of soil. The higher the BD value, the lower the soil OM [27], the denser the soil, and the lower the porosity [28]. So that it is increasingly difficult to pass water or be penetrated by plant roots.

3.2. Yield

In Figures 4 and 5, the effect of OM and PGPR treatment on ratoon rice yields is presented. The results of the statistical analysis did not show any significant differences. However, Figures 4 and 5 show that the average yield produced in the treatment of compost, rice husk charcoal, and PGPR inoculation is higher than the control. The highest yields were obtained in the treatment of rice husk charcoal and the application of PGPR (2.3 tonnes/ha).

Figure 4. Effect of treatment combinations on ratoon rice yields; C1P1 = without OM, non inoculated PGPR; C1P2 = without OM, inoculated PGPR; C2P1 = compost, non inoculated PGPR; C2P2 = compost, inoculated PGPR; C3P1 = rice husk charcoal, non inoculated PGPR; C3P2 = rice husk charcoal, inoculated PGPR; (means followed by the same letter differ significantly at alpha 0.05).
The results of this study are in line with [29], that the application of the *Synechococcus* sp. And the organic fertilizer dosage of 8 kg/plot was effective in increasing the yield of ratoon rice. The treatment of compost, rice husk charcoal, and inoculation of PGPR was able to increase the resistance of ratoon rice plants to drought stress and provide nutrients for the growth and development of ratoon rice which in turn increased ratoon rice yields. Zaki et al. [30] states that compost and rice husk charcoal reduced the damage caused by drought. Anesta et al. [31] in their research stated that the addition of PGPR was able to increase the weight of 1000 grains of rice grain compared to controls. According to [15], the application of PGPR to soybeans can reduce drought stress and significantly increase chlorophyll and leaf relative moisture content. PGPR has the potential for sustainable agriculture which is used as an alternative strategy to increase plant tolerance to abiotic stress, such as drought [32]. Giving endophytic fungi to tomato plants can reduce the negative effects of water stress or drought during plant growth and development [33]. The PGPR treatment can bind more water and reduce hydraulic conductivity and soil evaporation rates [34]. PGPR can increase the absorption of macro and micronutrients by plant roots and increase yields and soil quality [35]. The application of PGPR to green beans can increase yields (76%) [14].

### 3.3 Biomass

In Figures 6 and 7, the effects of organic matter and PGPR treatment on ratoon rice biomass are presented. The results of the statistical analysis did not show any significant differences. However, Figure 7 shows the highest average biomass produced in the compost treatment and PGPR application (15.5 g).
Figure 6. Effect of treatment combinations on the total biomass of ratoon rice; C1P1 = without OM, non inoculated PGPR; C1P2 = without OM, inoculated PGPR; C2P1 = compost, non inoculated PGPR; C2P2 = compost, inoculated PGPR; C3P1 = rice husk charcoal, non inoculated PGPR; C3P2 = rice husk charcoal, inoculated PGPR; (means followed by the same letter differ significantly at alpha 0.05).

Figure 7. Ratoon rice biomass is given OM (a) and PGPR (b); C1 = without giving OM; C2 = compost; C3 = rice husk charcoal; P1 = non inoculated PGPR; P2 = inoculated PGPR; error bar represents standard error.

These results are in line with Zafar [36], that the organic amendment in the compost form can increase plant productivity. Schulz [37] explained that compost applied to the soil can provide support for bacterial growth, increase soil aggregates, water holding capacity, and soil pH. Compost also increases the biomass of oat [37]. The application of PGPR to green beans can increase the total biomass (54%) [14]. PGPR significantly increased biomass in Brassica juncea [38]. Vigna radiata L. plants were able to increase biomass (61.2%) and seed weight (65.3%) compared to controls [39]. Increased biomass of tomatoes (31%), okra (36%), and African spinach (83%) compared to controls [40].

4. Conclusions
The organic amendment and PGPR can increase crop yields and plant resistance to drought stress by maintaining soil moisture and root elongation mechanisms. Based on the research results, the addition of rice husk charcoal and PGPR inoculation is the best combination for salibu ratoon rice cultivation in the rainfed dry land.
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