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Changes in soil fertility, growth and yield of ratoon rice (*Oryza sativa* L.) by application of soil amendment under drought stress

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Abstract: Rice (*Oryza sativa* L.) is a global staple food source with high demand. The influence of global climate change will impact rice production, one of which is drought condition. This research aims to determine the role of soil amendments on soil fertility, growth and yield of two rice varieties after ratooning on soil with low fertility under drought stress. The soil used in this study is Ultisol dryland from Jantho Aceh Besar, Indonesia. The study used a 3 x 2 x 2 split-split plot design with 3 replications. Soil amendments as the main plot consisted of vermicompost (7.5 g pot^{-1}), AMF (7.5 g pot^{-1}) and biofertilizer 17.64 mL L^{-1}, which were given in main rice crop 5 days before planting, 14 DAP, 28 DAP and 42 DAP. Drought as a sub-plot consisting of normal soil watering and drought stress conditions and rice varieties as a sub of sub-plot, namely IPB 9G and Inpago 12 varieties. The parameters observed were soil fertility, growth of ratoon and rice yield. The results showed that the application of AMF during drought stress increased soil fertility as indicated by the ECe value for both varieties, respectively 282.33 µS cm^{-1} and 276.67 µS cm^{-1}. The application of AMF also improves leaves chlorophyll content, plant height, number of tillers and number of plant leaves and yield. Rice productivity after ratooning reached 2.41 tons ha^{-1} in the IPB 9G variety and 1.84 tons ha^{-1} in the Inpago 12 variety under drought stress.

Keywords: **S**ustainable agriculture, pH, ECe, Chlorophyll content, Mycorrhiza, Vermicompost and Biofertilizer
Abbreviations: AMF_Arbuscular mycorrhizal Fungi; NPK_Nitrogen, Phosphorus, and Potassium; pH_Potential of Hydrogen; ECe_Electrical Conductivity of a saturated soil Extract; SPAD_soil plant analyze development; DAP_Days After Planting; DAR_Days After Ratoon; WAR_Weeks After Ratoon

Introduction

Improvement in the global population has triggered a significant increase in food needs, especially in staple foods like rice (Pandian et al., 2024). In the future, the world will face a big challenge in fulfilling food needs as a consequence of the growth of population and change of lifestyle. The United Nations estimates that the world population will be somewhere around 9.7 billion in 2050, which means food requests will increase by 50% compared to the current need (Rivero et al., 2021). The condition will demand improvement in agriculture productivity to ensure the resilience of global food.

However, the increasing agricultural productivity faces the challenge of water scarcity as a consequence of climate extreme. The Impact of drought that occurs in various world hemispheres has threatened the productivity of rice plants, especially in the country consumers of rice such as Indonesia (Kumar et al., 2019). Prolonged drought can cause water stress on plants, inhibit growth, and lower yield. This also impacts on decline of soil fertility, loss of soil elements for rice growth and yield (Rahman, 2019).

Soil amendments like vermicompost, mycorrhiza (AMF), and biofertilizer can increase soil quality. Vermicompost, is an organic matter capable of increasing the capacity of soil water retention sources (Castellini et al., 2024). AMF functions as a biological agent that helps root plants absorb more water and nutrition, especially phosphorus which increases the relative water content in the leaves and maintains the rate of plant photosynthesis (Maulina et al., 2021). Biofertilizer as a type of environmentally friendly fertilizer, play a role in increasing rice adaptation to drought. Biofertilizer contain plant growth promotion rhizobacteria (PGPR) that help fix soil structure, increase porosity, and reduce the water needs of plants (Ghosh et al., 2024). The use of biofertilizer as support for sustainable agriculture that does not only increases crop production but also guards environmental sustainability (Yang et al., 2023).

Besides soil amendment, the election of drought-resistant rice varieties becomes an important adaptation strategy to face global warming impact. Rice superior varieties such as IPB 9G and Inpago 12 have developed with drought resistant characteristics. Superior rice varieties can grow optimally even though limited water supply (Rajendran et al., 2021).

Superior varieties are not only tolerant to drought but also capable produce high yields, although in less profitable environments. Implementation of drought variety and soil amendment can become a holistic solution to overcome the challenge of climate change impact (Choudhary et al., 2016). The combination of sustainable agriculture techniques and regenerative farming becomes an alternative for rice production to fulfill global food needs. Especially with the cultivation of ratoon rice as an alternative to overcome water shortages. Ratoon rice does not require seedling so it is possible to continue production in conditions of water shortages after the main rice crop season (Wu et al., 2023).

Overall, this approach not only answers the need for food increasing, but also supports resilience in food with mitigation impact of climate change. This approach aiming to ensure that the use of soil amendment and superior variety become solution to overcome impact of drought as consequence of global warming which happening worldwide.

Results and Discussion

Soil pH after rice ratoon due to interaction of soil amendment, drought, and variety

Soil pH after ratooning due to the interaction of soil amendment and drought with different rice varieties is shown in Figure 1.

There was a change in soil pH in weeks 1-3 after ratooning due to interactions between soil amendments and drought in the two rice varieties. In the first week, the lowest pH was found in the vermicompost treatment at IPB 9G during drought stress, which was not different from giving biofertilizer to Inpago 12 during drought stress but was significantly different from the other treatments. In the second week, the lowest was found in the AMF and vermicompost treatment during drought stress on the IPB 9G variety and the provision of vermicompost on the Inpago 12 variety is in normal condition. In the third week, the lowest pH was found in the biofertilizer treatment applied to the IPB 9G variety under drought stress.

The ability of vermicompost, biofertilizer and AMF soil amendments to buffer soil pH in dry and wet conditions can be seen from the pH not increasing or decreasing significantly in drought stress conditions. This is due to the ability of vermicompost as an organic material that contains various mineral compounds to block cations which cause an increase in soil pH (Lopez et al., 2021). Likewise, biofertilizer also contain various nutrients and soil microbes that produce various exudates which can maintain soil moisture even if it is not irrigated (Kumar et al., 2017). AMF has exudates and hyphae that are able to moisten the soil and neutralize toxic compounds that can increase soil pH (Sladkovska et al., 2022).

Even though the soil pH remained normal in all treatments, there was a tendency for the pH to increase when AMF was used in normal conditions while using Inpago 12. This shows that AMF can increase pH more when used in water-sufficient soil compared to under drought stress (Chareesri et al., 2020) , this is in agreement with Yasier (2022) and Feng et al. (2023) research shows that although AMF can produce organic acids which can help lower soil pH, but under normal conditions the production of organic acids such as citric acid and oxalic acid are often not significant enough to directly lower soil pH even can increase soil pH. In addition, under certain conditions, AMF can increase the absorption of H^+ ions by plants, which has the potential to reduce soil acidity and cause the pH to rise (Fall et al., 2022).

Where the drier the soil, the higher the concentration of minerals in the soil due to the low water content to dissolve nutrients in line with the statement by Mu et al. (2023). When the soil dries out, the reduced water will increase the concentration of dissolved nutrients, such as Calcium, Magnesium, and Potassium ions, which have the potential to increase soil pH. However, AMF can help withstand these pH changes by optimizing nutrient absorption, thereby preventing the accumulation of minerals in the root zone. In addition, AMF also helps improve soil structure and water availability which play a role in maintaining pH balance under drought stress conditions in line with the statement by Thakur and Shinde (2020).

Soil temperature after rice ratooning due to interaction of soil amendment, drought, and variety

Soil temperature after ratooning due to the interaction of soil amendment and drought with different rice varieties is shown in figure 2.

The optimal soil temperature for all soil amendments shows the ability to maintain stable soil temperature. The soil temperature of 20-35ºC is the optimal temperature for rice plants to develop roots and grow. Observed data by Kumar et al. (2022) displays lower data that rice root growth was gradually inhibited when the soil temperature was above 34ºC. All soil amendment treatments showed soil temperatures that remained in optimal conditions even in drought conditions as research conducted by Firoozi et al. (2017) states that organic materials like vermicompost and biofertilizer are able to stabilize soil temperature. If the soil temperature is optimal, it will also be very good for the development of soil microorganisms which play a role in soil fertility.

The highest soil temperature was found in the vermicompost treatment under drought stress, indicating that vermicompost has a lower ability than biofertilizer and AMF in maintaining soil temperature under drought stress. Biofertilizer has properties that support more efficient water absorption. The nutrient content in biofertilizer helps maintain soil moisture balance, reduces evaporation, and lowers, especially when the soil is in water shortage conditions in line with the statement by Ichsan et al. (2024). Biofertilizer has good water-binding properties, so they can maintain moisture around plant roots in line with the statement by Ali et al. (2022). This slows down water loss from the soil and reduces the increase in soil temperature under drought conditions, which is beneficial for plants under drought stress.

Meanwhile, AMF forms a symbiotic relationship with plant roots, allowing AMF hyphae to absorb and store more water than plant roots alone in line with statement by Püschel et al. (2020). Better water retention in the soil maintains soil moisture, which contributes to lowering soil temperature in dry environments. This effect is especially important under drought conditions because temperature stability can help plants reduce stress and maintain optimal physiological activity.

Soil electrical conductivity after rice ratooning due to interaction of soil amendment, drought, and variety

ECe of soil after ratooning due to interaction of soil amendment and drought with different rice varieties is shown in figure 3.

The highest ECe was found in the biofertilizer treatment of the IPB 9G variety without drought stress (290 µS cm $^{-1}$), indicating the ability of biofertilizer under normal conditions to increase the ECe value of the soil, so that the soil has more nutrients available such as research results by (El-akhdar et al., 2024). But unfortunately, biofertilizers are unable to maintain soil ECe in drought conditions. This is different from AMF which has a better ability to increase soil ECe for both varieties Inpago 12 and IPB 9G during drought stress conditions respectively 282,33 µS cm $^{-1}$ and 276.67 µS cm $^{-1}$ compared to normal conditions which only show 248.67 µS cm $^{-1}$ and 226.33 µS cm $^{-1}$ in 2 WAR. AMF has the unique ability to increase soil ECe values, especially under drought stress conditions (Kazemi et al., 2019), due to their role in improving water (Syamsyiah et al., 2021)(Nazirah et al., 2018) and salt dynamics in the soil (Parvin et al., 2019).

AMF forms a symbiotic relationship with plant roots, increasing the uptake of water and nutrients from the soil through an extensive network of hyphae (Iqbal et al., 2020). These hyphae reach into smaller soil pores, helping to draw in water that plant roots cannot directly access (Mbodj et al., 2018). Under dry conditions, AMF also contributes to the release of certain ions (such as Calcium, Magnesium, and Potassium) into the soil solution through the process of dissolving minerals and exuding organic compounds. This increases the concentration of dissolved salts in the root zone, which is reflected in the increase in ECe values (Chitdeshwari et al., 2020). Additionally, AMF help maintain soil structure by increasing soil aggregation through the production of glomalin (Hossain, 2021), a soil protein that increases water retention and soil stability. The combined ability of AMF to increase water availability, support ionic activity, and maintain soil stability (Pang et al., 2020) makes them important agents in increasing ECe, even under drought stress. Where the minimum value of soil ECe suitable for cultivating drought-resistant rice plants is between 200-2000 µS cm^{-1} (Dwi et al., 2023).

Chlorophyll content after rice ratoon due to interaction of soil amendment, drought, and variety

The chlorophyll content of rice plants after ratooning due to the interaction of soil amendment and drought with different varieties are shown in Figure 4.

The use of vermicompost on the IPB 9G rice variety has the best ability to increase the amount of chlorophyll. Vermicompost plays a role by providing nitrogen and other nutrients that support chlorophyll formation in line with the statement by Ichsan et al. (2024). But during drought stress the plants using vermicompost setbacks in chlorophyll content. In contrast to the Inpago 12 variety, this variety does not have significant differences in chlorophyll content both under normal conditions and under drought conditions. This shows that Inpago 12's ability in drought conditions is better than IPB 9G.

Likewise, the AMF treatment was more able to associate with Inpago 12, so that the chlorophyll content when dry were higher than normal conditions as statement by (Zhang et al., 2016) AMF have different interactions with each variety. If compared, the use of AMF on the Inpago 12 variety is the best during drought because it has higher chlorophyll levels. AMF can increase rice chlorophyll levels because of their role in improving nutrient absorption (Askari et al., 2017), especially phosphorus (P), nitrogen (N), and microelements such as magnesium (Mg) and iron (Fe), which are important in chlorophyll synthesis (Khan et al., 2022). By increasing the availability and efficiency of nutrient absorption, rice plants can produce more chlorophyll, which plays a role in the photosynthesis process (Thakur et al., 2018). In addition, AMF also helps plants deal with environmental stress, such as drought and nutrient deficiencies (Khaliq et al., 2022), which can have a negative impact on chlorophyll production.

Plant height after rice ratooning due to interaction of soil amendment, drought, and variety

Plant height after ratooning due to interaction of soil amendment and drought with different rice varieties is shown in Figure 5.

The figure shows that the provision of AMF and biofertilizer is able to have a good impact on the height growth of IPB 9G and Inpago 12 rice varieties. This is shown by the absence of differences in plant height during normal and drought conditions when AMF is applied. AMF helps reach and absorb nutrients, especially phosphorus (P) and nitrogen (N) (Rui et al., 2022). Biofertilizer can increase the height of rice plants because it contains beneficial microorganisms which play a role in increasing the availability and efficiency of absorption of essential nutrients (Farid et al., 2022). Microbes such as phosphate-solubilizing and nitrogen-fixing bacteria in Biofertilizer help provide essential nutrients. Phosphorus plays a role in cell division and root system development, while nitrogen plays a role in protein synthesis and growth hormones such as auxin and cytokinin, which stimulate stem elongation (Sun et al., 2020).

Meanwhile, application of vermicompost only had a significant impact on the IPB 9G variety. This is thought to be due to differences in nutritional needs and absorption in IPB 9G and Inpago 12. As statement by Pan et al. (2016) different varieties have differences in nutritional needs and absorption. Each rice variety has different nutrient requirements that are influenced by genetic, physiological, and growing environmental factors (Dwiningsih et al., 2022).

Number of tillers after rice ratoon due to interaction of soil amendment, drought, and variety

The number of tillers after ratooning due to the interaction between soil amendment and drought with different rice varieties is shown in Figure 6.

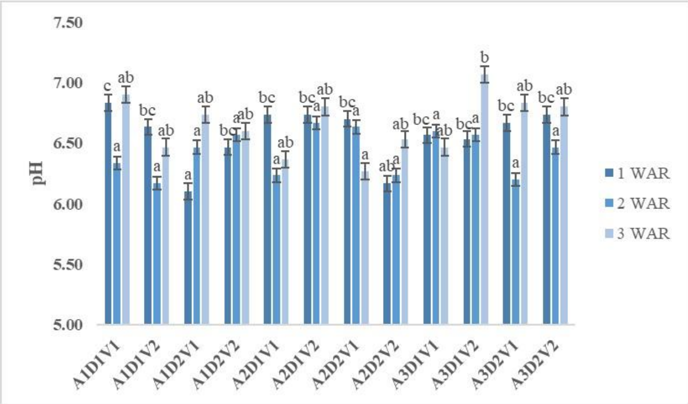

Figure 1. Soil pH at 1 - 3 week after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety. *The bars followed by the same letter each week are not significantly different (DMRT; P ≤ 0.05)

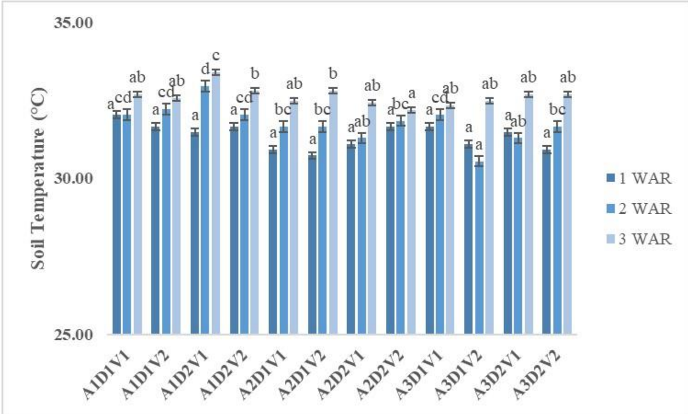

Figure 2. Soil temperature at 1 - 3 week after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety. *The bars followed by the same letter each week are not significantly different (DMRT; P ≤ 0.05)

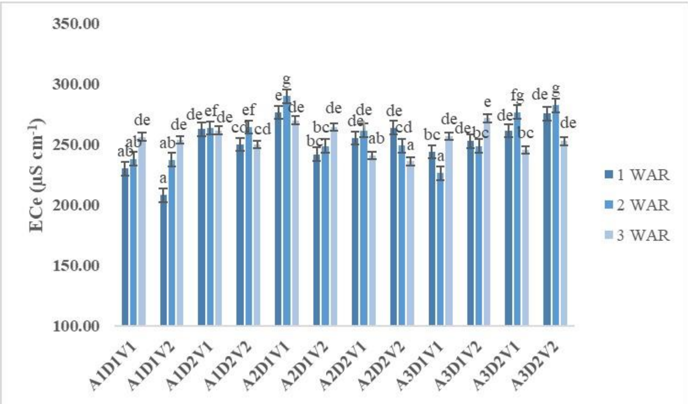

Figure 3. Soil ECe at 1 - 3 week after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety. *The bars followed by the same letter each week are not significantly different (DMRT; P ≤ 0.05)

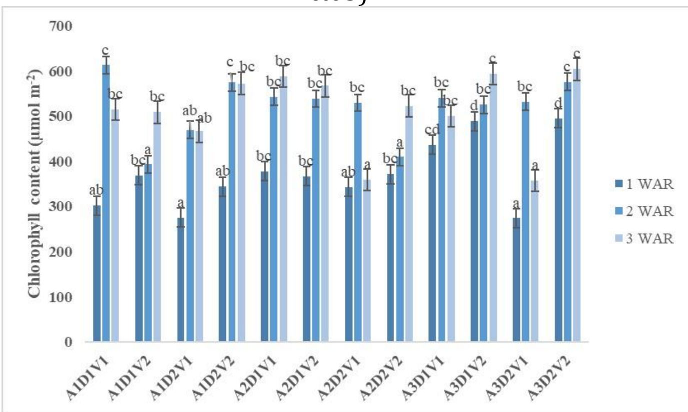

Figure 4. Chlorophyll content at 1 - 3 week after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety. *The bars followed by the same letter each week are not significantly different (DMRT; P ≤ 0.05)

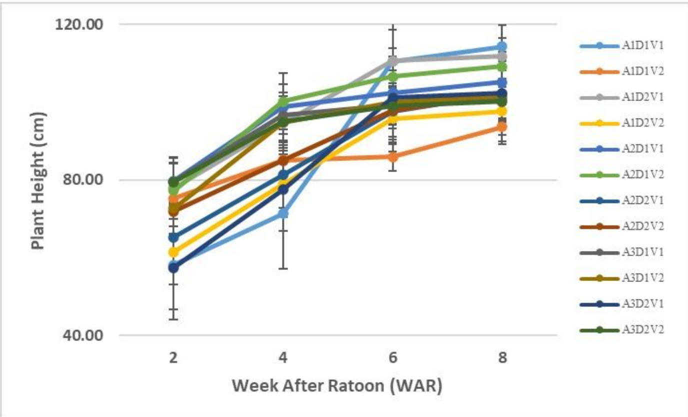

Figure 5. Plant height at 2, 4, 6 and 8 weeks after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety.

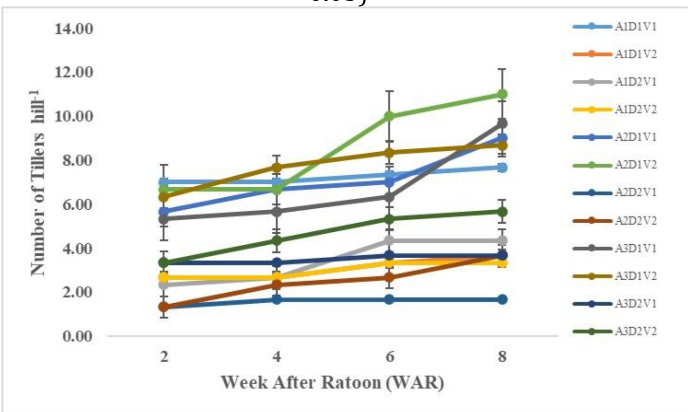

Figure 6. Number of tillers hill^{-1} at 2, 4, 6 and 8 weeks after ratoon (WAR) due to the influence of soil amendment type, drought, and rice variety.

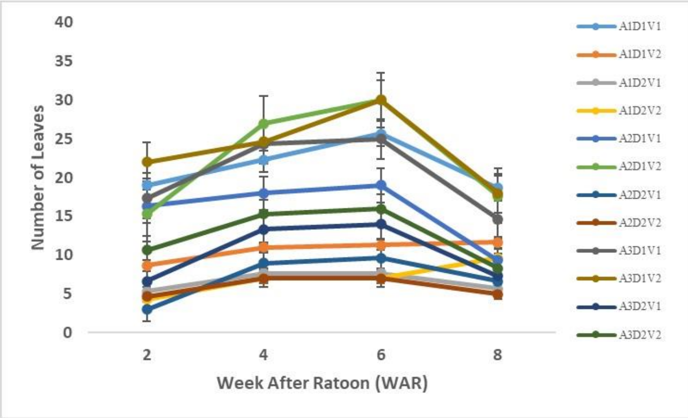

Figure 7. Number of leaves at 2, 4, 6 and 8 weeks after ratoon **(**WAR**)** due to the influence of soil amendment type, drought, and rice variety.

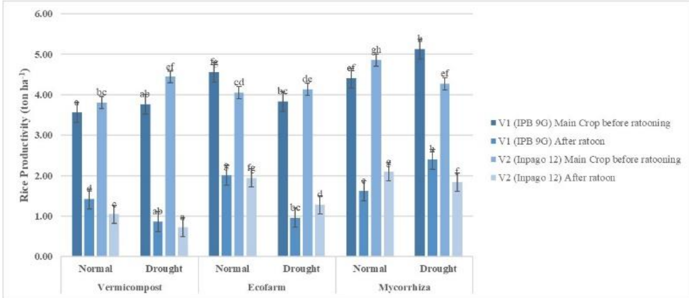

Figure 8. Rice Productivity in main plant and after ratoon due to the influence of soil amendment type, drought, and rice variety. *The bars followed by the same letter each harvest are not significantly different (DMRT; P ≤ 0.05)

The highest number of tillers in normal conditions is shown by the provision of biofertilizer on the Inpago 12 variety, while in drought stress conditions it is shown by the Inpago 12 variety with the provision of AMF application. Biofertilizer is able to increase the number of tillers in rice plants because this system optimizes the ecological balance in cultivation, so that plants can grow healthier and more productively (Bhardwaj et al., 2014). Biofertilizer also reduces the use of synthetic chemicals that can disrupt the balance of soil microorganisms (Alnaass et al., 2023), thereby increasing the availability of nutrients for rice plants (Fitriatin et al., 2021).

AMF also plays a role in increasing the availability of Phosphorus, which is an important nutrient in cell division and the growth of new tillers of rice and wheat (Akbar et al., 2023; Mitra et al., 2024). Adequate Phosphorus will stimulate stronger root growth (Campo et al., 2020), allowing plants to survive better in dry conditions and still be able to produce tillers (Etesami et al., 2022). AMF also helps plants reduce the impact of drought stress and defense enzymes that reduce damage from oxidative stress (Bahadur et al., 2019). With AMF, rice plants have better resistance to environmental stress and are still able to produce an optimal number of tillers even in drought conditions.

Number of leaves after rice ratoon due to interaction of soil amendment, drought, and variety

The number of leaves after ratooning due to the interaction of soil amendment and drought with different rice varieties is shown in Figure 7.

In Figure 7 there is a significant difference in the number of leaves under normal conditions and drought stress. Under normal conditions, the highest number of leaves was found in the biofertilizer and AMF treatments on the Inpago 12 variety. This was due to genetic factors which Inpago 12 is an upland rice variety which have better vegetative growth including greater leaf production (Zahara et al., 2024). Number of leaves is closely related to the number of tillers, Inpago 12 has a higher tillering potential than IPB 9G, then naturally the number of leaves formed will also be greater.

Rice plants with AMF treatment during drought conditions have more leaves compared to vermicompost and biofertilizer. This shows that AMF is able to overcome plant inhibition in cell division and elongation in the formation of new (Liao et al., 2018). However, rice that is given drought treatment tends to have fewer leaves due to obstacles in the formation of new leaves because the rate of cell division and elongation decreases (Bhandari et al., 2023), so leaf growth becomes slower. In addition, drought also accelerates the senescence process of leaf aging, where old leaves dry out and fall off more quickly as a plant response to save water.

Rice Productivity in main plant and after ratoon due to the influence of soil amendment type, drought, and rice variety

Figure 8 shows the highest productivity of the main crop before ratoon and ratoon rice are found in the IPB 9G variety with the use of AMF in under drought stress. The productivity of rice before ratooning the IPB 9G variety with AMF treatment was 4.41 t ha^{-1}. Meanwhile, rice productivity in drought stress conditions reached 5.1 t ha^{-1}. Likewise, ratoon rice has a productivity of 1.63 t ha^{-1} and under drought conditions 2.41 t ha^{-1}. This shows that AMF has an important role in maintaining the physiological ability of rice during drought stress. AMF can increase the expression of genes and enzymes (He et al., 2020; Singh et al., 2020) associated with defense mechanisms against drought stress, such as increased production of antioxidants and osmolytes (such as proline) (Chun et al., 2018). This helps plants reduce the negative impacts of drought and increases survival and crop yields.

The presence of AMF also contributes to increased water retention in the soil, by the production of glomalin (Singh et al., 2020), a substance that improves soil structure and increases its capacity to hold water longer. In addition, plants associated with AMF are able to regulate stomata better by playing a role in stimulating the production of hormones such as abscisic acid (ABA) (Xu et al., 2018), so they can reduce water loss through transpiration without disrupting the process of photosynthesis. With these various mechanisms, plants that are symbiotic with AMF are not only more resistant to drought, but in some cases are also able to produce higher yields than plants that grow under normal conditions. Besides that, the provision of AMF is the most influential factor in poor soil amendment (Fall et al., 2022).

Even though IPB 9G under drought stress with AMF has fewer tillers compared to Inpago 12 which is under drought stress, IPB 9G shows higher production. This relates to rice with fewer tillers can allocate more nutrients, water, and energy to each panicle, thereby increasing grain size and weight per panicle (Jiang et al., 2023). In contrast, we hypothesized that rice with many tillers under drought stress must divide resources among more growing points, which can reduce the size and weight of grain per panicle. IPB 9G chlorophyll levels during drought conditions with the application of AMF are also relatively low compared to plants with other treatments. The ability to produce higher productivity possibility because plants with lower chlorophyll content may have more efficient light distribution within the canopy, so that more sunlight enters the underside of the leaves, increasing the overall photosynthesis process of the plant (Slattery and Ort, 2021). Leaves with higher chlorophyll are often too thick and suffer from "light saturation", where excess chlorophyll cannot be used to its full potential (Stratoulias and Toth, 2020), thereby not increasing crop yields proportionately. Plants with a higher root weight under drought stress conditions are one of the plants' efforts to reach water (Wasaya et al., 2018) resulting in a lack of sinks into the panicles causing reduced yields. Other causes are the quality of the grain produced, the percentage of filled and empty grains, and the weight of 1000 grains (Jiang et al., 2016).

Materials and Methods

Materials and tools

After harvest the main crop, the rice plant stems were cut using plant shears leaving 20 cm of stems above the ground surface. The tools and materials used include 10 kg of soil capacity pots, soil rapid test analyzer, conductivity meters, SPAD meters Minolta 502, Ultisol Jantho soil with very low fertility levels (pH 5.1 - 6.02, C organic 0.32%, N total 0.11%, P total 1.1 mg kg^{-1}, K total 0,3 mg kg^{-1}, P available 0.9 ppm, Ca-exch 1.54 cmol kg^{-1}, Mg-exch 0.67 cmol kg^{-1}, K-exch 0.10 cmol kg^{-1}, Na-exch 0.75 cmol kg^{-1}, sum of cation 3.13 cmol kg^{-1}, CEC 20 cmol kg^{-1}, ECe 0.04 dS m^{-1}, and base saturation 12%). Ultisols Jantho Aceh Besar has low fertility (McLeod et al., 2020), rice varieties namely IPB 9G and Inpago 12, vermicompost (N 1.2%, P 0.9%, K 1.5%), biofertilizer (N total 3.35%, P_2O_5 5.4%, K_2O 1.47, C-organic 51.06%, C/N 15.24), and AMF(*Glomus sp., Acaulospora sp.,* and *Gigaspora sp.*) soil amendments, as well as urea and NPK fertilizers as basic fertilizers.

Place and time

The study was conducted at Greenhouse 2 (5°34'00.8"N 95°22'20.3"E), Faculty of Agriculture, Syiah Kuala University from June to November 2024. The minimum temperature is 27.29^{0}C and the maximum is 36.21^{0}C, the minimum air humidity is 76.15%, and the maximum is 84.13% with a height of 0.8 meters above sea level.

Experimental design

The study used a 3 x 2 x 2 split-split plot design with 3 replications. Soil amendments as the main plot consisted of vermicompost (A1), AMF (A2) and biofertilizer (A3) which were given in main crop before ratooning at 5 days before planting, 14 days after planting (DAP), 28 DAP, and 42 DAP in the main crop. Drought as a sub-plot consisted of two levels, namely normal soil water content by watering the plants every morning and evening (D1) and drought stress conditions by watering the plants when the leaves rolled up with a score of 5 (D2) at 65 to 85 days after planting (DAP). After ratooning, drought treatment is carried out at the age of 28-42 days after ratoon DAR. Rice varieties as sub of the sub-plot were the IPB 9G (V1) and Inpago 12 (V2) varieties.

Conduction of study

Vermicompost, AMF, and biofertilizer were given in the main crop before ratooning at 5 days before planting, 14, 28, and 42 days after planting (DAP) at a dose of 7.5 grams per plant each time for vermicompost and AMF, and biofertilizer spraying with a concentration of 17.64 ml L^{-1}. Rice keeps watering until soil saturated with water from the time of planting until the age of 65 days after planting (DAP). Drought stress was carried out after the plants entered the reproductive phase until the fruiting phase or 65-85 DAP. Drought treatment was carried out by stopping watering until the plants showed drought stress in the form of curled leaves at a score of 5, then watering was carried out again until saturated with water and the drought treatment was repeated until heading phase (86 DAP). Fertilization was carried out by providing 150 kg ha^{-1} urea fertilizer and 900 kg ha^{-1} NPK as basic fertilizer given at planting time, 30 and 42 DAP each 1.5 g of soil in main crop session and repeat after ratoon with the same doses. Ratoon plants received drought stress treatment in the reproductive phase at 28-42 DAR with the same provisions as the main crop.

Observed variables

The variables observed were soil pH, soil temperature (use Soil Rapid Test Analyzer) soil electrical conductivity (ECe) (use EC meter), Chlorophyll content, plant height, number of leaves, number of tillers $hill^{-1}$ and rice productivity in main crop and ratooning crop. Measurement of chlorophyll content using a SPAD meter Minolta 502, the results of which are then converted to μmol m^{-2} using the formula (Markwell et al., 1995):

Chlorophyll content (μmol m^{-2}) = $10.6 + 7.39 \times SV + 0.114 \times SV^2$

SV = SPAD Value

Statistical analysis

The variables observed due to differences in treatments given in the form of soil amendments, drought and varieties were tested using the ANOVA. Then further analyzed using DMRT (Duncan's Multiple Range Test) with a level of 5% by using software MS-Excel.

Conclusion

Application of AMF was able to increase soil fertility as indicated by the ECe value for both varieties Inpago 12 and IPB 9G, respectively 282.33 µS cm^{-1} and 276.67 µS cm^{-1} under drought stress. AMF not only helps plants manage water but also plays a role in soil amendments, so that the soil becomes more fertile. The application of AMF also increases leaf chlorophyll content, improves plant growth including plant height, number of tillers and leaves as well as rice productivity after ratoon. Rice productivity after ratooning reached 2.41 tons ha^{-1} in the IPB 9G and 1.84 tons ha^{-1} in the Inpago 12 varieties on low fertility Ultisol. The application of AMF beneficial to increase ratoon rice yield under drought stress compared to vermicompost and biofertilizer.

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Authors contributions

Cut Nur Ichsan: research concept, research design, analysis, methodology, writing original draft. Erida Nurahmi: data collection, writing review. Trisda Kurniawan: editing and review discussion. Mutiah Hasibuan: data collection and writing. Cut Huzaifah: Data collection. Akhsani: data collection. Aisyah Fitri: Analysis, discussion and editing.

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