Growth response of rice (*Oryza sativa* L.) plant towards magnetized seawater treatment

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Abstract. Climate change has impacted many sectors, especially ecology and agriculture which are related to water supply and quality. The amount of available fresh water on Earth has been less than 1%, potential effects include drought, water quality impairment, and saltwater intrusion to coastal water supplies. An alternative to overcome the shortage of fresh water in the agricultural sector is to substitute freshwater with other sources of water, for example, seawater. Seawater availability is 97%, but it cannot be used directly in the agricultural sector due to the high salinity of seawater. High salinity causes numerous disturbances to the growth of the plant. The ability of a magnetic device for seawater desalination can be used in this research to evaluate seawater potential for irrigation water. This research aims to analyze the growth response of rice plants ‘IR 64’ and ‘Inpari 35’ with magnetized seawater treatments. This experiment was conducted using a randomized design with three factorials, i.e., rice cultivars (‘IR 64’ and ‘Inpari 35’), level of seawater salinity (0 and 10 dS m⁻¹), and type of magnetized seawater (untreated and treated by magnetic treatment). The experiment result showed that magnetized seawater treatment decreased salinity level in seawater to minimize the negative impact of salinity on the growth of rice plants as indicated by increasing plant height, number of leaves, plant biomass, carotenoid, and chlorophyll content.

1. Introduction

Climate change has a significant impact on many sectors such as agriculture, which is related to water resources. Available freshwater has decreased significantly in the last decade accounting for less than 1% of the water on earth and 70% of its use in agriculture [1][2]. Insufficient water can disrupt crop growth and production [3]. Accordingly, it is necessary to seek an alternative that can be used to overcome the shortage of fresh water for irrigation in the agricultural sector. Based on these, seawater is considered a realistic alternative in agriculture, either desalinized or combined with freshwater [4].

Seawater is the most abundant water resource on Earth accounting for around 97% of the Earth’s water while almost 2% is locked in ice [2]. Seawater contains nutrients, trace elements, and microorganisms that are beneficial to plant growth and development [5], but seawater has a high salinity at around 30–35 ‰ [6] with a pH value ranging from 7.5–8.5 [7]. Seawater cannot be used directly for plant irrigation because it contains high salinity. The application of water containing excess salt for irrigation may cause toxicity to plants because they can affect nutrient absorption and assimilation, enzyme activity, photosynthesis, protein expression, and hormone metabolism in plants, resulting in reduced leaf area, necrosis, abrasion, disruption of ionic balance [8]. Therefore, seawater can not be used directly for agriculture irrigation [9].

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One of the strategies that can be used to minimize the effect of seawater is using conjugative use (CU) of seawater and freshwater. This strategy has been demonstrated more efficient in alleviating the effect of saline water on crop growth [10]. The use of CU is not always feasible, especially when the salinity of water exceeds the salinity tolerance threshold of the plant [11]. According to Ali et al [12], magnetized water decreases the hydration of salt ions, increases the mobility of nutrients in the soil, improves the effectiveness of fertilizers, and increases the availability and absorption of N, P, K, Fe, and Zn in plants [13]. In addition, Alikamanoglu and Sen [14] reported that magnetized water increased soil microbial content and plant resistance to unfavorable environments. Based on de Vos et al. [15] use of seawater irrigation showed that irrigation water up to a salinity level of 5–7 dS m$^{-1}$ can be used for crop production of some varieties of the tested crops (potato, cabbage, onion, carrot, lettuce and barley) without any yield loss. Therefore, magnetic treatment for seawater irrigation could be one of the encouraging ways in the future to enhance agricultural production in response to climate change nowadays [16].

The largest agricultural sector in Indonesia is rice which is a staple food commodity. According to the ministry of agriculture [17], rice production for five years has increased annually by 2.33%. The high productivity of rice plants coincides with problems in the planting process, such as drought stress and salinity. Symptoms of salinity toxicity in rice plants include stunted growth, reduced tillers, whitish leaf tips, and chlorosis, toxicity also affects the electrical conductivity (EC) value of 6-10 dS m$^{-1}$ which causes a decrease in the yield of up to 50% [18]. The use of suitable and adaptive superior cultivars can be an alternative for rice production as in the current climate change. ‘IR64’ and ‘Inpari 35’ are superior rice cultivars that have different characteristics. ‘Inpari 35’ is salt-tolerant, whereas ‘IR64’ is a salt-susceptible rice cultivar [19]. Alternative use of water for agricultural irrigation is needed along with the decreasing availability of fresh water, one of which is by analyzing the potential of seawater as irrigation water. The objective of this research is to analyze the growth response of rice ‘IR 64’ and ‘Inpari 35’ with magnetized seawater treatments to determine the potential seawater for agricultural irrigation under current climate change conditions.

2. Materials and methods
This research was carried out in the Sawitsari Research Station and Plant Physiology Laboratory Faculty of Biology UGM. This experiment was conducted using a randomized design with three factorials, i.e., rice cultivars (‘IR 64’ and ‘Inpari 35’), level of seawater salinity (0 and 10 dS m$^{-1}$), and type of magnetized seawater (untreated and treated by magnetic treatment). Magnetic water device from JOTO valve and pump China. Seawater from Porok beach, Gunung Kidul Regency, Yogyakarta.

Rice seeds were immersed in ethanol 70% for 5 minutes and followed by 0.2% HgCl4 for 2 minutes, after that seed was rinsed with sterile aquadest and germinated into polybag containing 4 kgs of loamy sand soils. Magnetized water treatment was carried out by flowing conjugative water (seawater mixed with fresh water according to the salinity level) through a magnetized water device. Magnetized seawater treatment is given at 14 days after planting (DAP). Magnetic treatments were applied for 2 weeks by watering with 250 ml of magnetized water every day. Measurement of growth parameters includes plant height, number of leaves, and number of tillers. Plant height, number of leaves, and number of tillers were measured every week. Environmental parameters such as soil moisture and soil pH were measured once a week until the end of the treatment.

Analysis of chlorophyll content in this study refers to Yoshida et al. [20] with slight modifications. Analysis of chlorophyll and carotenoid content using leaves from plants that have reached the final vegetative development stage. The leaves are taken as much as 0.1 gram and then crushed using liquid nitrogen to become a fine powder. The leaf extract is added with 10 ml of 80% acetone, then centrifuged. Then the supernatant was transferred to a new tube and covered with aluminum foil. The absorbance measurements were carried out with a wavelength ($\lambda$) of 470, 663 and 645 nm. The absorbance results shown on the spectrophotometer are then used to calculate the chlorophyll and carotenoid content. The data obtained were then tested by the Independent Sample T-test with a 95% confidence level.
3. Results and discussion

Water is considered one of several abiotic factors that affect plant growth and development. Magnetized water is referred to as magnetic field water treatment. In this study, the potential of magnetized seawater is evaluated in relation to the growth of two rice cultivars that have different characteristics. The results showed the positive effects of magnetized seawater on the growth of both rice cultivars. Rice plants that watered with magnetized seawater grew taller than those watered with fresh water (Figure 1). The effect of magnetized seawater is more visible on the height growth of IR 64 rice plants. This relates to the character of IR 64 which is sensitive to salinity so that the 10 dS m$^{-1}$ magnetized seawater treatment will reduce the salinity of seawater. Salinity affects the absorption of water by plants. The reduced salinity of watered water allows plants to absorb water used for growth. It may due to the effect of magnetized water on reducing salinity stress by increasing salt movement through the soil profile [21]. Magnetic treatment of seawater also affected phytohormone production leading to improved cell activity and plant growth [22].

![Figure 1](image)

Figure 1. Plant height of rice of the rice (Oryza sativa L. ‘IR 64’ and ‘Inpari 35’) towards magnetized seawater treatment. Level of seawater salinity 0 (A) and 10 dS m$^{-1}$ (B). Without-magnetized treatment (M0) and with magnetized treatment (M1).

Magnetized seawater treatment significantly affected plant height, but did not have an effect on leaves number (Table 1). The level of seawater salinity also affects plant height. Plant height in treatment with a salinity level of 10 dS m$^{-1}$ was lower than control. Plant height measured at 28 days after planting which means 14 days after treatment with magnetized water was significantly taller than control. The electromagnetic fields from magnetization increase the plant growth regulator that induced phenylalanine ammonia-lyase during cell differentiation in the suspended cultured plant cell. Plants irrigated with magnetized water easily take up mineral from the soil and no residue on the soil surface [23][24], also, promote vegetative growth and the plant ripen earlier than normal. Therefore the plants are supplied with sufficient nutrients for proper growth stage and metabolic processes, which help to improve the rates of all growth parameters and plant growth.

Magnetized seawater treatment also significantly affected plant biomass as indicated by the increase in fresh weight of shoot and root (Table 2). The fresh weight of root and shoot of both cultivars treated with magnetized seawater was higher than that without magnetized water treatment. This finding is consistent with the research of Maheswari and Grewal [22] which showed that an increase in plant height is also reflected in an increase in biomass with magnetized water treatment. In addition, Sadeghipour and Aghaei [23] found that magnetized water induced a significant increase in cowpea biomass, stomatal conductance and water use efficiency. Magnetic treatment affects the biochemical and physical reaction of water that affects plant biochemical reactions, including enzymatic activity. Magnetic treatment increased the nutrient and water uptake and cell permeability resulting in an increase in plant biomass [24].
Table 1. Plant height and leaves number of rice (*Oryza sativa* L ‘IR 64’ and ‘Inpari 35’) at 28 days after planting (DAP) towards magnetized seawater treatment.

| Parameters       | Cultivars   | Level of seawater salinity | Magnetized treatment |
|------------------|-------------|----------------------------|----------------------|
|                  |             |                            | without | with  |
| Plant height* (cm) | ‘IR64’     | 0 dS m⁻¹                    | 23.3ᵃ   | 25.5ᵇ  |
|                  |             | 10 dS m⁻¹                   | 21.0ᵃ   | 27.2ᵇ  |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 35.4ᵃ   | 39.1ᵇ  |
|                  |             | 10 dS m⁻¹                   | 33.9ᵃ   | 38.7ᵇ  |
| Leaves number**  | ‘IR64’     | 0 dS m⁻¹                    | 4       | 4      |
|                  |             | 10 dS m⁻¹                   | 3       | 3      |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 4       | 4      |
|                  |             | 10 dS m⁻¹                   | 4       | 4      |

Note. Mean followed by the same letter in the same row was not significantly different with independent T test at α 0.05. *:significant; ns: non-significant.

Table 2. Plant biomass of rice (*Oryza sativa* L ‘IR-64’ and ‘Inpari 35’) at 28 days after planting (DAP) towards magnetized seawater treatment.

| Parameters       | Cultivars   | Level of seawater salinity | Magnetized treatment |
|------------------|-------------|----------------------------|----------------------|
|                  |             |                            | without | with  |
| Fresh weight shoot* (g) | ‘IR64’     | 0 dS m⁻¹                    | 0.24ᵃ   | 0.25ᵇ  |
|                  |             | 10 dS m⁻¹                   | 0.13ᵃ   | 0.24ᵇ  |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 0.61ᵃ   | 0.62ᵇ  |
|                  |             | 10 dS m⁻¹                   | 0.40ᵃ   | 0.66ᵇ  |
| Fresh weight root* (g) | ‘IR64’     | 0 dS m⁻¹                    | 0.05ᵃ   | 0.06ᵇ  |
|                  |             | 10 dS m⁻¹                   | 0.03ᵃ   | 0.05ᵇ  |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 0.13ᵃ   | 0.14ᵇ  |
|                  |             | 10 dS m⁻¹                   | 0.12ᵃ   | 0.15ᵇ  |

Note. Mean followed by the same letter in the same row was not significantly different with independent T test at α 0.05. *:significant; ns: non-significant.

Table 3. Chlorophyll and carotenoid content of rice (*Oryza sativa* L ‘IR-64’ and ‘Inpari 35’) at 28 days after planting (DAP) towards magnetized seawater treatment.

| Parameters       | Cultivars   | Level of seawater salinity | Magnetized treatment |
|------------------|-------------|----------------------------|----------------------|
|                  |             |                            | without | with  |
| Chlorophyll* (mg g⁻¹ FW) | ‘IR64’     | 0 dS m⁻¹                    | 2.65ᵃ   | 2.98ᵇ  |
|                  |             | 10 dS m⁻¹                   | 2.24ᵃ   | 2.79ᵇ  |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 3.04ᵃ   | 3.52ᵇ  |
|                  |             | 10 dS m⁻¹                   | 2.71ᵃ   | 3.46ᵇ  |
| Carotenoid** (mg g⁻¹ FW) | ‘IR64’     | 0 dS m⁻¹                    | 1.28     | 1.36    |
|                  |             | 10 dS m⁻¹                   | 1.25     | 1.29    |
|                  | ‘Inpari 35’| 0 dS m⁻¹                    | 1.30     | 2.22    |
|                  |             | 10 dS m⁻¹                   | 1.26     | 2.36    |

Note. Mean followed by the same letter in the same row was not significantly different with independent T test at α 0.05. *:significant; ns: non-significant.

Table 3 shows chlorophyll and carotenoid content on rice plants treated with magnetized water irrigation significantly higher than control. The effect of magnetized water was also tested by Abobatta [25] showing the results that offering magnetic water can increase rice growth, photosynthetic pigment...
content, organic components, and total protein in rice. Magnetized water treatment can significantly induce cell metabolism and mitotic cell division meristematic, so as to accelerate the growth rate in plants. The increase in photosynthetic pigments occurred in chlorophyll a, b, and total chlorophyll treated with magnetic water, indicating that there was an improvement in ion mobility and ion absorption after being treated with magnetic water. It can also accelerate the rate of photosynthesis and increase the accumulation of assimilates for the vegetative growth of a plant [26].

Chlorophyll and carotenoids are essential photosynthetic pigments, plant health indicators, and are considered as a stress response mechanism. Chloroplast has paramagnetic properties which can be affected by magnetic treatment by increasing ion mobility and ions uptake which leads to better photostimulation and growth. Moreover, the magnetic field has the ability to change water properties, thus magnetized water increased rice chlorophyll content [27]. In line with the research findings of Tian et al. [28], magnetized water has the potential to increase the level of assimilatory pigments which increased the chlorophyll content of rice plants.

4. Conclusion
Magnetized seawater treatment significantly affected in plant height, plant biomass, chlorophyll, and carotenoid content. 'IR 64' and 'Inpari 35' showed positive responses to the magnetized seawater treatment. Based on this research, the use of magnetized seawater 10 dS m⁻¹ is potential as an alternative irrigation water for rice cultivation.

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