Research Article

BIOMEDICAL
Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2023.51.008140

Effects of Water Stress on Seed Germination of Paddy *Oryza sativa*: a Preliminary Laboratory Experimental Study

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ARTICLE INFO

Received: June 29, 2023

Published: July 21, 2023

Citation: Tze Yik Austin Hew, Muhammad Adam Mohd Roslan, Maisarah Defififaldi, Muhammad Ezzafel Shafu Azhar, Muhammad Darwish Nazhan Ismail, Mohamad Saupi Ismail, Wan Mohd Syazwan, Hideo Okamura, Yoshifumi Horie, Meng Chuan Ong, Ahmad Dwi Setyawan, Krishnan Kumar, Wan Hee Cheng, Rosimah Nulit and Chee Kong Yap. Effects of Water Stress on Seed Germination of Paddy *Oryza sativa*.: a Preliminary Laboratory Experimental Study. Biomed J Sci & Tech Res 51(4)-2023. BJSTR. MS.ID.008140.

ABSTRACT

Paddy or also known commonly as rice is one of the staple food plants, especially for the Asian community. Thus, this makes paddies vital as a main source of carbohydrates. Paddy's main factor that determines survivability is the water stress level. Through this experiment, we determined to observe the effect of water stress on the early growth of selected rice, evaluate the effect of water stress on the germination of rice seeds, observe the growth and development of plants from rice seeds and decide the critical periods for rice crops for water stress. In this experiment, two sets of paddy plants were planted and received daily watering with varying amounts of water, respectively. The result came out showing that there are significant differences in growth rate in both samples where the one that has been watered with less water show a significantly low growth rate and germination rate. In conclusion, through this preliminary experiment,, it is found that water stress levels play a significant role in paddy growth as it can affect the germination rate and also the growth rate of the paddy.

Introduction

More than half of the world's population relies on rice (*Oryza sativa L.*) as a staple food. On average of 161 million hectares worldwide, 678.7 million tonnes of rice are produced annually on average. Due to the great magnitude of their effects and widespread occurrence, drought is one of the key abiotic factors [1]. Abiotic stresses have the potential to negatively impact agricultural productivity [2] as well as an organism's physiological status by affecting its metabolism, growth, and development [3]. Abiotic stresses are also a significant contributor to crop failure, reducing the average yield of important crops by more than 50% and endangering the future viability of the agricultural sector [4]. High salt and water stress negatively affect processes like seed germination, seedling growth and vigour, vegetative growth, blooming, and fruit set, which leads to a decrease in economic output and product quality [5]. When exposed to various abiotic stresses, many plant species naturally assemble protein and proline as transcendent osmolytes. These substances are thought to serve an adaptive role [6]. Rice is one of the most sensitive crops due to its sensitivity to salt and drought conditions, making water/soil salinity and a lack of water a major global barrier to rice production [7,8].

Drought has become the most common soil issue in nations that cultivate rice in recent years and is seen as a significant global constraint on rising rice output [9]. The application of modern technologies has been attributed to an increase in rice yield by approximately 84% [10]. The main feature used for selection in genetics for drought tolerance is grain yield in stressful environments [11]. The impact of drought on seed production is related to how long plants were watered from flowering until they reached physiological maturity. The development of seedlings and germination is crucial for the early establishment of plants under stressful conditions [12]. The selection of varieties that exhibit rapid and uniform germination under water stress conditions can greatly contribute to the early establishment of seedlings. In this study, water stress has been used as one of the abiotic factors that probably will give an effect on the selected rice, especially on the germination and growth development part of the rice. The objectives of this study were to compare the effects of water stress on germination rate and also the growth rate of the paddy under laboratory experimental study.

Materials and Methods

The methods carried out for this experiment are as below. Two experimental conditions were set up: the control group received 200 ml of water, while the water stress group received 60 ml of water. Three replicates were prepared for each treatment. 500 g of soil was prepared in a plastic bag. Then, the rice seeds were sterilized with 70% ethanol for 15 minutes and were rinsed with autoclaved double distilled water four times. This method is to prevent any bacteria or virus contamination of the seeds. Plastic pots were filled with 500 g of soil, and five paddy seeds were then placed at approximately equal distances from each other within the pots. The seeds were watered with 200 ml (as control) and 60 ml (as water stress) respectively, every day on the morning. Daily observations of seed germination were conducted until day 21. The germination percentage was calculated using the following formula [13,14]:

Germination percentages (% GP) = (number of healthy seedlings / total number of seeds in the test) / 100

On the 21st day, the height of the seedlings was measured using a ruler. Seed vigor was determined using the calculation method described by Abdul-Baki and Anderson [15], as shown below:

Seed vigor;

$$V1 = \text{Seedling Length} \times \text{Germination }\%,$$
$$V2 = \text{Seedling Dry Weight} \times \text{Germination }\%$$

The T-test between any two variables was conducted using the STATISTICA soft ware package

Results and Discussion

Table 1: Comparison of the growths of paddy seedlings between the control and water-stressed treatment.

Treatment	Average height (cm)	Average number of seeds germinated	Average fresh weight (g)	Dry weight (g)
Stress	8.75 ± 1.84A	5.00 ± 1.00A	0.0236 ± 0.0067A	0.0154 ± 0.0063A
Control	12.31 ± 12.3B	9.00 ± 1.00B	0.0353 ± 0.0103B	0.027 ± 0.0026B

Note: Alphabets with different letters indicate the Stress and Control are significantly ($P< 0.05$) different.

The overall effects of water stress from the present experiment are presented in (Table 1). From the experiment conducted, it can be seen that the average height of the paddy seedlings under stress is lower (8.75 cm) than the control (12.31 cm). The paddy seedling height under stress treatment has lower height when compared to under control treatment by 3.56cm. This could be due to the water stress that can affect stomatal activity, which in turn affects CO_2 absorption [16], which in turn affects photosynthesis and plant growth. The functioning of ion and water transport mechanisms across membranes is crucial in the regulation of guard cell turgor pressure changes and the facilitation of stomatal closure, particularly in response to water deficit stress [17]. Therefore, water stress affects the growth of the paddy seedling as it slows down its height. As for the number of paddy seedlings that were germinated, it can be seen that the number of seeds germinated under stress is lower (5 seeds) than control (9 seeds). The difference of four led to a factor of, with increasing

DOI: 10.26717/BJSTR.2023.51.008140

water stress, all genotypes experienced a drop in seed germination percentage and seedling growth [18]. It has been demonstrated that a reduction in the water potential gradient between the external environment and the seed is the primary cause of the inhibition of radicle emergence during water stress [19].

Lesser water quantity may cause a tiny pore in the seed, known as micropyle to absorb lesser water and subsequently affects the seeds germination and further physiological processes [20]. Other than that, the fresh weights of the paddy seedlings were also recorded in. It can be seen that the fresh weight of Paddy seedlings under stress is lower (0.0236 g) than the control (0.0353 g). The fresh weight of paddy under stress treatment is 0.0236g, while the fresh weight under control treatment is 0.0353g. This is because plants under water stress have lower water potential and turgor pressure (Blackman, 2018), which causes the solute concentrations in the cytosol and extracellular matrix to increase [21,22]. Cell enlargement consequently declines, which inhibits growth and impairs reproduction which causes the fresh weight of the paddy under stress treatment to be lower compared to paddy under control treatment [22]. The germination percentage for stress and control treatments is calculated via the formula of germination percentage (%), hence germination percentage for stress and control is 33.33% and 60.00% respectively (Table 2).

Table 2: Comparison of average height, average dry weight, and estimated seed vigor between the control and water-stressed treatment.

Treatment	Average height (cm)	Average dry weight (g)	Estimated Seed vigor (V1)	Estimated Seed Vigor (V2)
Stress	8.75 ± 1.84A	0.0154 ± 0.0063A	291.64	0.51
Control	12.31 ± 12.31B	0.027 ± 0.0026B	738.60	1.62

Note: Alphabets with different letters indicate the Stress and Control are significantly ($P< 0.05$) different.

Lastly, the dry weight of the paddy seedling was observed and compared. It can be seen that the dry weight of paddy seedlings under stress is significantly lower (0.0155 g) than control (0.027 g). Water shortage reduces nutrient uptake, transfer, and consumption at each growth stage, which reduces carbon storage and dry matter when considering the impact of drought stress on plants [23,24]. The difference in dry weight could be due to the nutrients weight as carbon, nitrogen, essential metals, trace metals and proteins [25]. When there is a water shortage, the general growth indicators, including cell size, cell division, cell wall composition, plant size, and both dry and fresh weight of the plant, all exhibit a decrease [26]. Overall, the number of seeds that germinate is higher in the control compared to the stress. The seed of the paddy contains an endosperm that gives energy and nutrition for the seed to germinate [27]. In order to germinate, imbibition needs to take place where water is important to hydrate and stimulate enzymes in the seed. As a result, the seed begins to release energy from its endosperm in order to expand. This causes pressure to build up in the cells of the embryo, forcing them to grow and leading to the seed coat rupturing. Therefore, the higher water input will increase the chance of germination.

Conclusion

In summary, the water stress affects the growth of the paddy seedling as it slows down its height. In terms of grain yield, the rice seeds replicate in water stress treatments reacted to water stress more compared to rice seeds in control treatments; specifically, yield reduction was greater under water stress treatment than underwater in the control condition. It appears that the percentage of yield decline relies on the water stressing percentages. Cell enlargement consequently declines, which inhibits growth and impairs reproduction that causes the fresh weight of the paddy under stress treatment to be lower compared to paddy under control treatment. In addition, the panicle initiation and flowering stages of the rice crop were more sensitive to water stressing than other growth stages, and as a result, their percentage yield drop was greater. Both treatments have 3 replicates which help to get more accurate results and observe the growth and development of plants from rice seeds. Moreover, since the formation of the primordial panicle until heading, rice crops are particularly sensitive to water limitations. The probability of germination is positively influenced by greater water input as a result of the elevated sterility rate. Managing drought stress during the reproductive stage becomes imperative due to its substantial impact on both yield and seed quality throughout the entire crop growth cycle.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2023.51.008140

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