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Evaluating Gibberellic Acid-Induced Seed Dormancy Release in Rice (*Oryza sativa* L.) for Enhanced Germination

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Abstract. Seed dormancy is a significant challenge in rice production, leading to uneven and poor germination rates. This study examines the effectiveness of gibberellic acid (GA_3) in enhancing rice seed germination by alleviating seed dormancy. The experiment was conducted from April to May 2024 at Barangay Mabini, Santo Domingo, Nueva Ecija, using a Completely Randomized Design (CRD) with six treatments (Control, 50 ppm, 75 ppm, 100 ppm, 150 ppm, and 200 ppm GA_3) and three replications. The primary objectives were to assess the impact of varying GA_3 concentrations on seed dormancy release in an inbred rice variety (NSIC Rc 160), determine the optimal concentration for maximum germination rates, and compare the germination and seedling emergence performance of GA_3-treated seeds with that of untreated seeds. The study analyzed critical germination data such as percent germination, and percent of seedling emergence, time to 10% germination and emergence (T_{10}), mean germination and emergence time (T_{50}), time to 90% germination and emergence (T_{90}), and mean spread of germination and emergence time (T_{90}-T_{10}). The results showed that GA_3 treatments at up to 150 ppm significantly increased germination rates compared to the control. The 50 ppm GA_3 treatment was remarkably efficient, resulting in a 100% germination rate in one setup and the fastest T_{10}. Higher concentrations (200 ppm) were shown to inhibit germination while significantly increasing T_{10}, T_{50}, and T_{90}. Optimal germination enhancement was observed at concentrations ranging from 50 to 150 ppm, with 50 ppm showing the most consistent improvement across all parameters. The study also found that GA_3 concentrations significantly improved the uniformity of germination and emergence times in rice cultivation. The 75 ppm treatment improved germination uniformity slightly, whereas higher concentrations (100 and 200 ppm) resulted in a slight increase in spread. The ideal concentration for increasing emergence uniformity was around 150 ppm. This study demonstrates that optimal GA3 concentrations can effectively break seed dormancy and enhance rice germination rates, providing valuable insights for improving rice production and food security. These results show that GA_3 can improve germination performance and seedling uniformity by breaking dormancy. The use of ideal GA_3 concentrations has the potential to enhance seed technology and promote sustainable rice production by facilitating more effective rice establishment.

Keywords: Gibberellic acid (GA_3); Phytohormones; Rice; Seed dormancy; Seed germination; Seedling emergence

1.0 Introduction

A crucial phase in the plant life cycle is the transition from seed dormancy to germination. The timing, synchronization, and intensity of this process have a direct impact on rice (*Oryza sativa* L.) crop growth, development, and tolerance to various climatic conditions (Xu et al., 2025). However, a significant obstacle to rice production is seed dormancy, which frequently results in inconsistent and poor germination, leading to lower yields and poorer stand establishment. The fundamental genetic and physiological mechanisms supporting rice seed dormancy are still not fully understood, despite the identification of specific genes associated (Chen et al., 2023).

Plant hormones play a crucial role in the intricate relationship between internal and environmental variables that influence seed germination. Gibberellins (GAs) and abscisic acid (ABA) are the primary antagonists; whereas ABA promotes dormancy and increases stress resistance, GAS promote germination. In the end, a seed's ability to germinate is determined by the hormonal balance between GA and ABA, both in terms of content and sensitivity (Gong et al., 2022). The molecular and hormonal regulation of germination in monocots, such as rice, remains unclear, despite the extensive research conducted in model organisms like Arabidopsis thaliana (Wang et al., 2024).

Several phases of development, including stem elongation, leaf expansion, senescence, and seed germination, are known to be regulated by gibberellins, particularly gibberellic acid (GA_3) (Ritonga et al., 2023). To facilitate germination, GA_3 softens the seed coat, mobilizes food stores, and stimulates the synthesis of hydrolytic enzymes. Moreover, it has been demonstrated that GA_3 promotes rice growth under unfavorable seasonal conditions, such as cold stress (Shashibhushan et al., 2021). Although the physiological effects of GA_3 are well established, limited studies have been done to determine the ideal amounts for breaking dormancy in specific rice cultivars. This study evaluates whether applying GA_3 to the inbred rice variety NSIC Rc 160 affects seed dormancy release, germination rate, and seedling emergence. The study aims to advance more sustainable rice production methods and enhance seed technology by determining the optimal concentration for germination.

2.0 Methodology

2.1 Research Design

The study employed a Completely Randomized Design (CRD) with three replications and six treatments. The treatments included: Control (untreated), 50 ppm GA_3, 75 ppm GA_3, 100 ppm GA_3, 150 ppm GA_3, and 200 ppm GA_3.

2.2 Research Locale

The experimental area was carried out in Barangay Mabini, Sto. Domingo, Nueva Ecija.

2.3 Data Gathering Procedure

The procedure involved seed collection and preparation, as well as the application of treatments independently. Inbred rice variety (NSIC Rc160) was used in this experiment. Seed cleaning involved removing debris and damaged seeds. The collected seeds were air-dried to achieve a uniform moisture content. Each treatment was replicated three (3) times. Treatments were applied to seeds of the test rice variety. GA_3 solutions of varying concentrations (50 ppm, 75 ppm, 100 ppm, 150 ppm, and 200 ppm) were prepared before seed soaking. A 75 % water-soluble gibberellic acid was used. Seeds were soaked in respective GA_3 solutions for a 24-hour duration, ensuring uniform absorption. Control seeds were soaked in tap water. The test variety (NSIC Rc160) has an initial germination percentage of 92 %. The age of the seeds, from harvesting to sowing, was 207 days. Two (2) set-ups were employed in this study, for seed germination (Set A), a clean microwavable plastic container was used. Each container was lined with a paper towel for germination. One hundred (100) seeds of each treatment were washed three (3) times and placed in a container. For seed emergence (Set B), fifty (50) seeds were sown in a plastic container filled with soil to a depth of 2 cm. All germinated seeds were monitored and counted every 24 hours.

2.4 Data Analysis

All collected data were subjected to analysis of variance (ANOVA) using the Statistical Tool for Agricultural Research (STAR) software. Treatment means were compared using the Least Significant Difference (LSD) test at a 5% level of significance ($P = 0.05$).

2.5 Ethical Considerations

This study did not require permission from an ethical review board because it solely utilized plant materials. However, mandatory ethical procedures in agricultural research were followed, including the safe disposal of experimental waste, the responsible use of chemicals, and the use of appropriate seed sources. The study did not use endangered species or genetically modified organisms (GMOs).

3.0 Results and Discussion

Percent Germination and Seedling Emergence

Data on percent germination and seedling emergence are shown in Figure 1. Set-up A (Seed Germination Test) data show favorable germination percentages across all treatments, with minimal variation. Treatments 1, 2, and 3 (0, 50, and 75 ppm) had a similar percentage of germination at 98.33%, indicating that these concentrations do not affect the germination of rice seeds. Germination percentage decreased slightly at higher concentrations (100, 150, and 200 ppm). The germination rate at 100 ppm was 96.33%, whereas the 150 and 200 ppm treatments resulted in 97.67% and 97.00% germination rates, respectively; however, these differences were not statistically significant ($p > 0.05$). These small reductions indicate a minor negative impact at greater concentrations, although overall germination rates remain high.

Set-up B (Seedling Emergence Test) showed that the 50 ppm treatment achieved 100% seedling emergence, but this was also not significantly different ($p > 0.05$) from the control and other treatments up to 200 ppm. However, a statistically significant decrease ($p < 0.05$) was observed at 75 ppm compared to 50 ppm, suggesting a potential threshold effect.

These results are consistent with Amorim et al. (2021), who emphasized that the use of high-quality seeds results in rapid growth and establishment of seedlings in the field. As a result, the accuracy of the information obtained while determining the physiological condition of seeds is important.

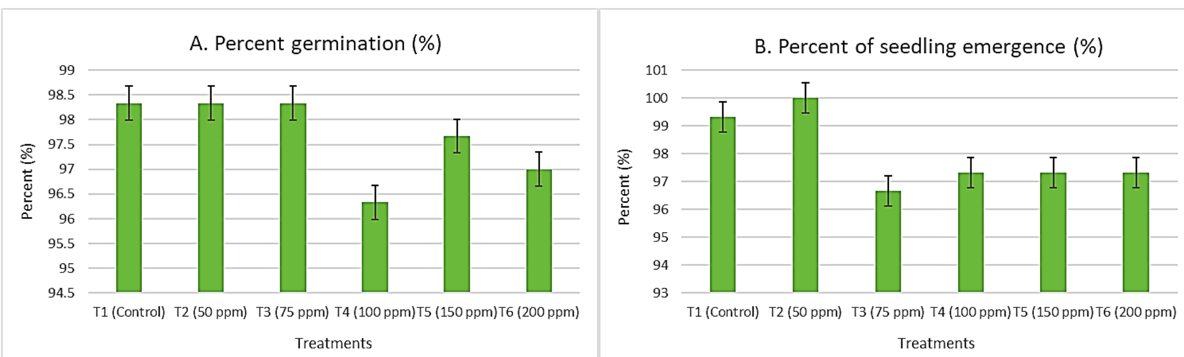

Figure 1. *Data on Percent Germination (Set-up A) and Seedling Emergence (Set-up B) as Influenced by Gibberellic Acid Treatment*

Time to Reach 10% Germination and Seedling Emergence (T_{10})

Data on the time to reach 10% germination and seedling emergence (T_{10}) is shown in Figure 2. In Set-up A, T10 ranged between 2.44 and 2.5 hours. Furthermore, the fact that these slight differences were not statistically significant ($p > 0.05$) suggests that GA_3 has a minimal influence on the timing of early germination. In Set-up B, the 50 ppm treatment showed the most effective concentration in promoting early seedling emergence ($p < 0.05$), as it considerably reduced the time to reach 10% seedling emergence (5.98 hours) compared to the control (7.56 hours). The emergence time increased significantly beyond 75 ppm (e.g., 18.2 hours at 200 ppm), indicating inhibitory effects at high concentrations ($p < 0.05$).

According to Shu et al. (2015), higher concentrations cause a significantly slower rate of emergence. Seed dormancy and germination are distinct physiological processes that play a crucial role in plant development and crop production. Plant hormones and environmental signals regulate these processes with efficiency. While ABA (abscisic acid) and GAs (gibberellins) are the primary phytohormones that regulate seed dormancy, a new study suggests that auxin, another phytohormone, plays an important role in inducing and maintaining seed dormancy, potentially acting as a key protection.

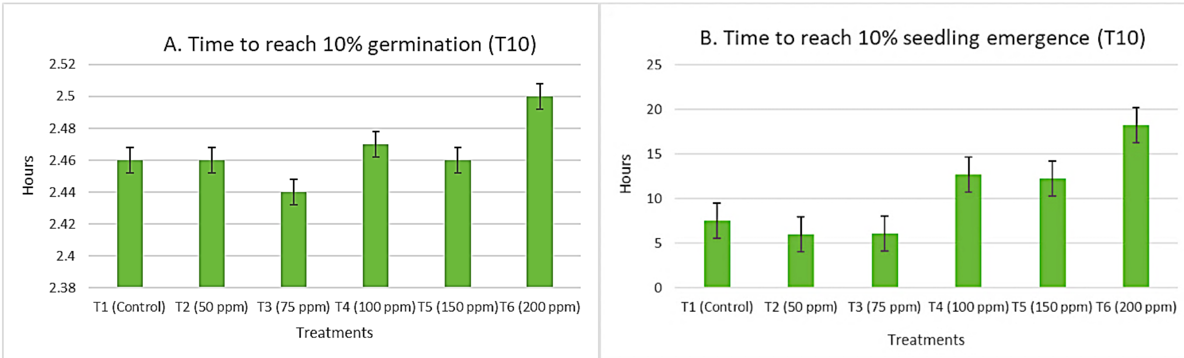

Figure 2. *Data on Time to Reach 10 % Germination (Set-up A), and Seedling Emergence (Set-up B) as Influenced by Gibberellic Acid Treatment*

Mean Germination and Seedling Emergence Time (T_{50})

Data on the time to reach 50% germination and emergence (T_{50}) are shown in Figure 3. Set-up A data were statistically comparable among the control, 50 ppm, and 75 ppm treatments ($p > 0.05$), with the 75 ppm treatment having the shortest mean germination time (12.2 hours), whereas the 50 ppm treatment had no effect compared to the control. The most significant inhibitory effect was observed at 200 ppm (12.51 hours), where the mean germination time is longer than in the control and other treatments. This shows that excessive amounts of the gibberellic acid can slow down the overall germination process. A similar trend was observed in a study on *Capparis spinosa* L., where seeds treated with 200 ppm GA_3 exhibited a lower germination rate (56.67%) in comparison to the control (68.33%). At higher temperatures, even lower rates were noted with 400 ppm and 600 ppm GA_3 (53.33% and 12.86%, respectively) (Chiboub et al., 2024).

Set-up B data show that lower treatment concentrations (50 ppm, 75 ppm, 100 ppm, and 150 ppm) increase seedling emergence time compared to the control. The most significant increase was observed at 50 ppm, followed by 150 and 75 ppm. At 100 ppm, there is still some improvement, although not as obvious. At 200 ppm, the mean emergence time is significantly longer than in the control and other treatments, showing an extreme inhibition of emergence. This shows that such high concentrations are damaging to seed emergence. Results revealed that the ideal concentration range for improving seedling emergence appears to be between 50 and 150 ppm. Within this range, seeds emerged faster than the control, with 50 ppm producing the highest results. These findings align with those of Li and Yang (2020), who found that GA treatment increased seed germination at low temperatures, while the production of GA inhibitors restricted germination.

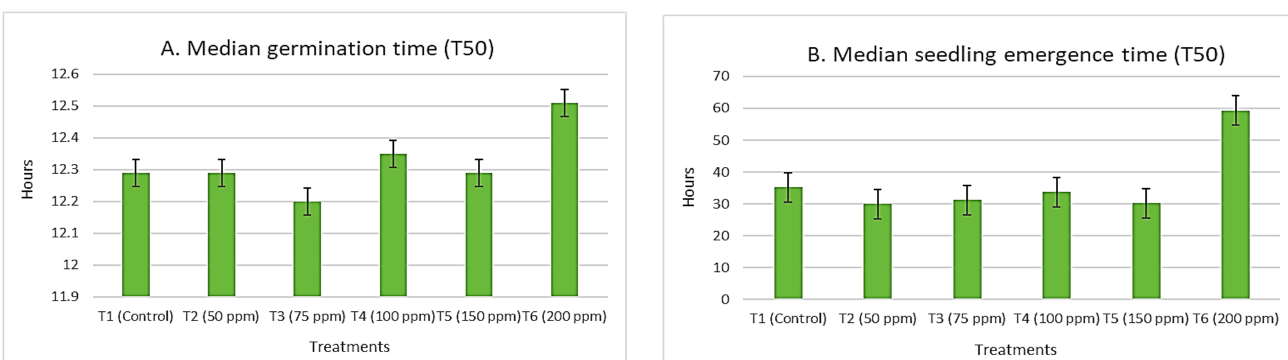

Figure 3. *Data on Time to Reach 50 % Germination (Set-up A), and Seedling Emergence (Set-up B) (T_{50}) as Influenced by Gibberellic Acid Treatment*

Time to Reach 90% Germination and Emergence Time (T_{90})

Data on the time to reach 90% germination (T_{90}) are shown in Figure 4. Set-up A results show that lower concentrations of 50 and 150 ppm had little effect on the time to 90% germination. The time was almost identical to the control, indicating that these concentrations have no significant effect on the overall germination process. At 75 ppm, the time to 90% germination is slightly faster than the control, demonstrating a small favorable effect on the germination rate. At 100 ppm, the time to 90% germination is slightly longer than that of the control, indicating a slight negative influence on germination. At 200 ppm, the duration to 90% germination is the longest, indicating a more substantial inhibitory effect on the germination process. Only the 200 ppm treatment caused a significant delay ($p < 0.05$), while the rest had no significant difference compared to the control. These results are consistent with research on the dose-response of GA_3, which indicates that high concentrations (≥100 ppm) can hinder the process. Specifically, 200 ppm has a strong inhibitory effect, whereas intermediate amounts (~50–75 ppm) may slightly accelerate germination to approximately T_{90}. In soybeans, Erol & Arslanoħlu (2022) found that mean germination durations were shorter at 100–150 ppm, but that 200 ppm raised MGT and decreased germination index. Similarly, at 50 ppm GA_3, Gentiana seeds germinated fastest, and the benefits decreased with increasing concentrations (Spies, 2023).

Set-up B data reveal that treatment concentrations ranging from 50 ppm to 150 ppm are beneficial for increasing seedling emergence, with 150 ppm being the most effective, which significantly reduces the time to reach 90% emergence ($p < 0.05$). These concentrations significantly decreased the time required to obtain 90% emergence when compared to the control. However, at 200 ppm, it resulted in the longest time ($p < 0.05$); this treatment becomes inhibitory, requiring more time to accomplish 90% emergence than the control. As a result, for the best rate of seedling emergence, concentrations between 50 ppm and 150 ppm should be utilized. In contrast, concentrations at or above 200 ppm should be avoided due to their unfavorable influence. These findings support a consistent pattern in previous research by Mohammed (2023), which shows that GA_3 doses ranging from 50 to 150 ppm significantly increase seedling emergence, with 150 ppm frequently resulting in the most significant decrease in time to 90% emergence (T_{90}). For instance, experiments conducted on soybeans showed a peak emergence percentage of approximately 59% at 150 ppm, exceeding both lower and higher doses and the control. By preventing seeds from germinating at the wrong times or under unfavorable conditions, seed dormancy is a crucial trait that enhances plant longevity. In rice, pre-harvest emergence on the parent plant, caused by a lack of seed dormancy, can reduce production and seed quality. Despite the discovery of several genes, our awareness of seed dormancy regulation remains limited (Huang et al., 2023).

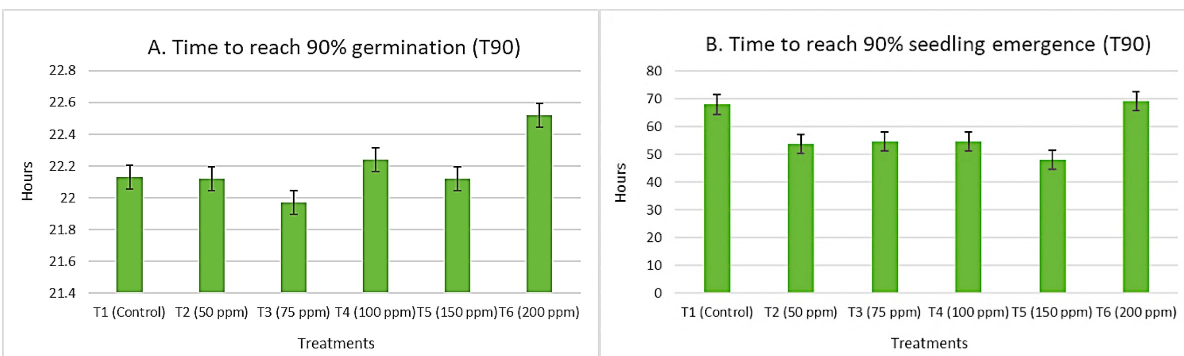

Figure 4. *Data on Time to Reach 90 % Germination (Set-up A), and Seedling Emergence (Set-up B) as Influenced by Gibberellic Acid Treatment*

Mean Spread of Germination and Emergence Time (T90–T10)

Data on the mean spread of germination and emergence time are shown in Figure 5. The mean spread of germination time remained stable across different treatments, with only minor variations. The 75 ppm treatment shows a slight improvement in the uniformity of germination. In comparison, the 100 ppm and 200 ppm treatments show a slight increase in the spread of germination times, indicating less uniformity. The overall differences are relatively insignificant, implying that the GA_3, at these concentrations, has no significant effect on the uniformity of germination times. The data indicate that there is no strong trend in how different concentrations of the substance affect the mean spread of germination time. However, higher concentrations (100 ppm and 200 ppm) may slightly decrease uniformity. All treatments had statistically similar means ($p > 0.05$), showing that GA_3 has minimal influence on the uniformity of germination timing. These results align with recent findings by Şahin et al. (2025), who reported that GA_3 treatments had a minimal influence on the uniformity of germination and early seedling growth. However, even under stress, Adhikari et al. (2022) found that maize germination consistently spread throughout GA_3 priming concentrations.

Set-up B data shows that all treatments with the GA_3 concentration reduce the mean spread of emergence time compared to the control ($p < 0.05$), indicating an improvement in the uniformity of emergence times. The 150 ppm treatment shows the most significant reduction in the mean spread of emergence time, suggesting it is the most effective concentration for improving uniformity. There appears to be a general trend that increasing the concentration up to 150 ppm improves the uniformity of emergence time. The 200 ppm treatment, while still better than the control, is less effective compared to the 100 ppm and 150 ppm treatments. The uniformity of emergence and the time required for emergence are crucial factors in achieving high yields in plants. Sowing depth and soil moisture influence uniformity and emergence, but little is known about the effects of seed vigor (Ebone et al., 2020).

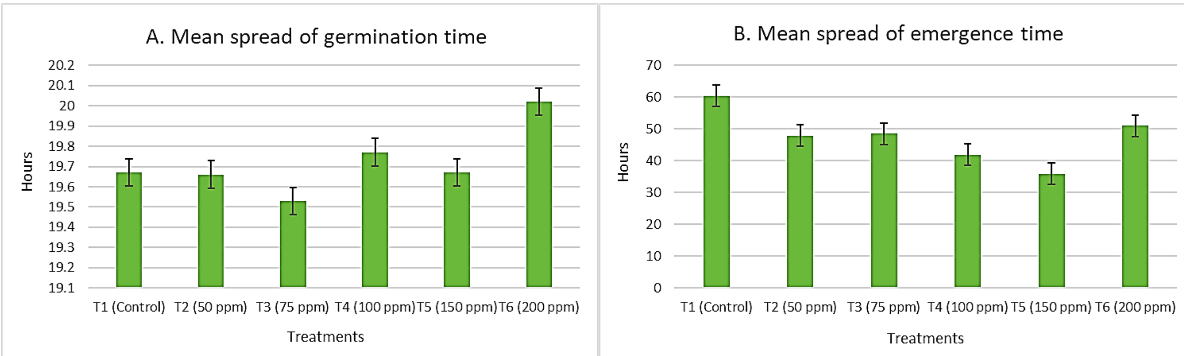

Figure 5. *Data on Mean Spread of Germination (Set-up A), and Seedling Emergence (Set-up B) Time (T_{90}-T_{10}) as Influenced by Gibberellic Acid Treatment*

4.0 Conclusion

The results showed that GA_3 treatments up to 150 ppm considerably increased the germination rate; in one setup, the 50 ppm treatment achieved 100% germination. On the other hand, germination was decreased by the highest dosage tested (200 ppm). At concentrations up to 200 ppm, GA_3 had no impact on seedling emergence; however, 100% emergence was still observed in the 50 ppm condition. The uniformity and speed of germination and emergence were enhanced at lower concentrations (50 to 150 ppm), with 150 ppm being the optimum concentration for enhancing emergence uniformity. Based on these results, it may be possible to break dormancy or improve early establishment in suboptimal field conditions by applying moderate GA_3 concentrations, particularly 150 ppm, to enhance seedling performance. Considering their inhibitory effects, greater quantities (such as 200 ppm) should be used with caution.

This study shows how GA_3 can be used as a seed treatment to enhance rice germination, particularly in controlled environments. To provide more helpful advice for farmers, it is advised that future research can confirm these findings in field settings, especially in anaerobic or stress-prone settings; assess the varietal response to GA_3 across a range of genotypes; and look into the long-term effects of GA_3 treatment on seedling vigor, plant growth, and yield performance.

5.0 Contributions of Authors

Author 1: Mirasol D. Del Rosario provided conceptualization of the study, designed the experimental framework, conducted the experiment, collected and analyzed data, and wrote the draft of the manuscript. Del Rosario, M., was primarily responsible for the execution and interpretation of the study.
Author 2: Manolo T. Valdez provided supervision, contributed to the study design, supported statistical analysis and interpretation of results, and reviewed and refined the manuscript. Both authors contributed to the final revision and approved the submitted manuscript version.

6.0 Funding

Department of Science and Technology - Science Education Institute (DOST-SEI).

7.0 Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

8.0 Acknowledgment

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