International Journal of Sustainability and Advanced Integrated Research
Volume 2, Issue 2 (April-June 2026) | ISSN: 3107-7854
DOI: https://doi.org/10.65339/ijsair.V2.I2.241

Productivity of Inbred Rice (*Oryza Sativa L.)* as Influenced by the Application of Gibberellic Acid (GA_3)

Shelah R. Ronquillo, RAgri[1], Prof. Artemio A. Martin Jr., PhD[2]
[1,2]Isabela State University, Echague Campus, Isabela, Philippines

Publication history: Received: March 29, 2026; Revised: April 12, 2026; Accepted: April 16, 2026
Email of Corresponding Author: shelah.r.ronquillo@gmail.com

Abstract

This study aimed to evaluate the effects of varying concentrations and application timing of Gibberellic acid 3 (GA_3) on the growth and yield performance of inbred rice (NSIC Rc 222). Grounded in plant physiological theory, the research examined how GA_3 influences vegetative and reproductive development under field conditions. A Randomized Complete Block Design (RCBD) was employed with ten treatments, including control groups and varying GA_3 concentrations applied at different growth stages. The study was conducted in Magassi, Cabagan, Isabela, using standard agronomic practices and field-based measurements such as plant height, tiller number, panicle length, culm length, grain filling, and yield. Data were analyzed using Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) test. Results revealed that GA_3 significantly increased plant height and culm length, particularly when applied at 25 and 50 days after transplanting. However, no significant improvements were observed in the number of productive tillers, panicle length, number of filled grains, grain yield per plot, or computed yield per hectare. In some cases, higher GA_3 concentrations resulted in reduced grain filling and lower yield performance. The findings indicate that GA_3 primarily enhances vegetative growth but does not improve reproductive development or overall yield. It is recommended that GA_3 application be minimized in inbred rice production under similar conditions, and further studies should explore alternative concentrations, timings, and site-specific factors. This study aligns with Sustainable Development Goals SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) by addressing sustainable rice production and efficient input use. The findings contribute to agricultural sustainability by promoting evidence-based practices that support resource efficiency, climate resilience, and improved farm productivity.

Keywords: Culm length, Gibberellic acid 3, Inbred rice, Plant height, Rice productivity, Yield performance

1. Introduction

Rice production remains critical to food security but is increasingly challenged by low productivity, climate change, and sustainability concerns. In the Philippines, heavy reliance on rice imports highlights persistent production gaps despite extensive cultivation. Enhancing rice productivity through scientific interventions such as plant growth regulators, particularly Gibberellic acid 3 (GA_3), offers a potential pathway to improve yield and resilience. This study examines the effects of GA_3 concentration and timing on the growth and yield performance of inbred rice, contributing to sustainable agricultural development.

1.1 Background of the Study on GA_3 Application and Inbred Rice Productivity

The agricultural sector faces significant challenges in sustaining rice production due to climate change, resource limitations, and declining yields, which negatively impact farmers' livelihoods. The Philippines remains dependent on rice imports, ranking as the world's leading rice importer from 2023 to 2024 due to low yields and post-harvest losses (PNA, 2024). Increasing population pressure further intensifies the need for improved food security aligned with SDG 2: Zero Hunger and sustainable production systems under SDG 12 (Stuecker et al., 2018). Rice (Oryza sativa L.) is a primary staple for over 80% of Filipinos and a major global cereal crop cultivated across 114 countries (Britannica, 2024). Beyond its nutritional value (Park, 2020), improving rice productivity is essential for sustaining livelihoods and ensuring food availability. One promising strategy involves the use of plant growth regulators (PGRs), which influence physiological processes such as growth and development (Sabagh et al., 2021). Gibberellic acid 3 (GA_3), a widely studied PGR, has been shown to enhance plant height, panicle development, and grain yield (Gavino et al., 2008). Its application contributes to improved crop resilience under abiotic stress conditions, supporting climate-smart agriculture and SDG 13: Climate Action.

1.2 Themes and Insights from Related Literature on GA_3, Growth, and Yield

Literature consistently demonstrates that GA_3 significantly influences plant growth processes, including germination, elongation, and flowering (Yamaguchi, 2008; Iqbal et al., 2011). It promotes cell division and elongation, leading to improved plant height and biomass (Chaudhary et al., 2004). Studies on rice indicate that GA_3 enhances seed yield, panicle exertion, and stigma exsertion, which contribute to higher fertilization rates (Thu et al., 2008). Similarly, hybrid rice production technologies incorporating GA_3 have increased yields by 15–20% (Peng, 2014; Ma and Yuan, 2015). Optimal concentrations and timing are critical, as they influence grain weight, seed vigor, and overall productivity (Zhou et al., 2017; Wang et al., 2019). Research across other crops supports these findings. GA_3 improves vegetative growth, fruit yield, and quality in crops such as tomato and strawberry (Mostafa and Saleh 2006; Gelmesa et al., 2012; Ozguven et al., 2000). However, excessive concentrations may reduce yield, indicating the importance of proper dosage (Hossain et al. 2019). Timing of application is equally important. Foliar application at specific growth stages, such as 20 days after transplanting, significantly improves rice growth and yield attributes (Ramesh, S. et al. (2019)). These findings highlight the need to optimize both concentration and timing for maximum effectiveness.

1.3 Local, National, and Global Context of Rice Production and Yield Challenges

Globally, rice production is concentrated in Asia, which accounts for over 90% of consumption and production (Britannica, 2024). In the Philippines, rice remains a staple food, yet production struggles to meet demand. National production reached 19.96 million metric tons, but consumption continues to exceed supply, leading to imports of 3.8 million metric tons in 2023 (PSA, 2024; Philrice, 2023). Regionally, Central Luzon leads production, followed by Cagayan Valley and Western Visayas (PSA, 2024). In Isabela, production reached 1.48 million metric tons, with Cabagan contributing 14,231 metric tons annually (Philrice, 2023). Despite these outputs, rising consumption and production inefficiencies maintain dependency on imports. Globally and locally, challenges such as climate variability, high production costs, and inefficient distribution systems continue to limit productivity, reinforcing the need for innovative and site-specific agricultural interventions.

1.4 Theoretical or Conceptual Basis of GA_3 Effects on Rice Growth and Yield

The study is grounded in plant physiological theory, particularly the role of plant growth regulators in modifying growth and development. GA_3 functions as a hormonal regulator that stimulates cell elongation, division, and reproductive processes (Heden and Thomas, 2012). It influences key growth parameters such as plant height, tillering, flowering, and grain formation, which directly affect yield outcomes. The effectiveness of GA_3 depends on concentration, timing, and environmental conditions, reflecting the interaction between plant physiology and agronomic management.

1.5 Research Gaps and Rationale on GA_3 Concentration and Timing in Inbred Rice

Although numerous studies demonstrate the positive effects of GA_3 on crop growth and yield, variability in results suggests that optimal concentration and timing remain context-dependent. Environmental conditions, crop variety, and application methods influence outcomes, necessitating site-specific research. Limited studies focus on inbred rice varieties under varying GA_3 concentrations and application timings within local Philippine conditions. This gap highlights the need to evaluate the interaction between GA_3 rates and timing to determine optimal practices for improving yield performance.

1.6 Alignment with Relevant Sustainable Development Goals (SDGs)

This study aligns with several Sustainable Development Goals, particularly SDG 2: Zero Hunger, by aiming to enhance rice productivity and contribute to improved food security amid increasing demand and import dependence (PNA, 2024). It also supports SDG 12: Responsible Consumption and Production through the efficient use of plant growth regulators to optimize agricultural inputs and improve production sustainability (Stuecker et al., 2018). Furthermore, the application of Gibberellic acid 3 (GA_3) to enhance crop resilience under varying environmental conditions contributes to SDG 13: Climate Action, as it promotes adaptive and climate-smart agricultural practices that help mitigate the impacts of climate variability on rice production.

1.7 Importance of the Study to Multidisciplinary Sustainability in Agriculture

The study contributes to socio-economic sustainability by improving farmer productivity and income through optimized agricultural practices. It supports agricultural and environmental sustainability by promoting efficient resource use and climate-resilient crop management. Additionally, it advances technological and innovation sustainability by integrating plant physiology with agronomic practices. The findings provide practical guidance for farmers, extension workers, and policymakers, contributing to policy and institutional sustainability in agricultural development.

2. Material and methods

2.1 Research Design

The study utilized a Randomized Complete Block Design (RCBD) to evaluate the effects of different GA_3 concentrations and application timings on inbred rice. There were ten treatments per replication, including two control treatments without GA_3 and eight treatments with varying GA_3 concentrations and timing schedules. Treatments included 175,000 ppm, 200,000 ppm, 225,000 ppm, and 250,000 ppm per hectare applied at different growth stages. This design allowed comparison of both individual and interaction effects of GA_3 concentration and timing.

2.2 Locale of the Study

The study was conducted in an irrigated field located in Magassi, Cabagan, Isabela. The site is adjacent to a residential area and provided suitable conditions for rice production, including water availability and accessibility for crop management operations.

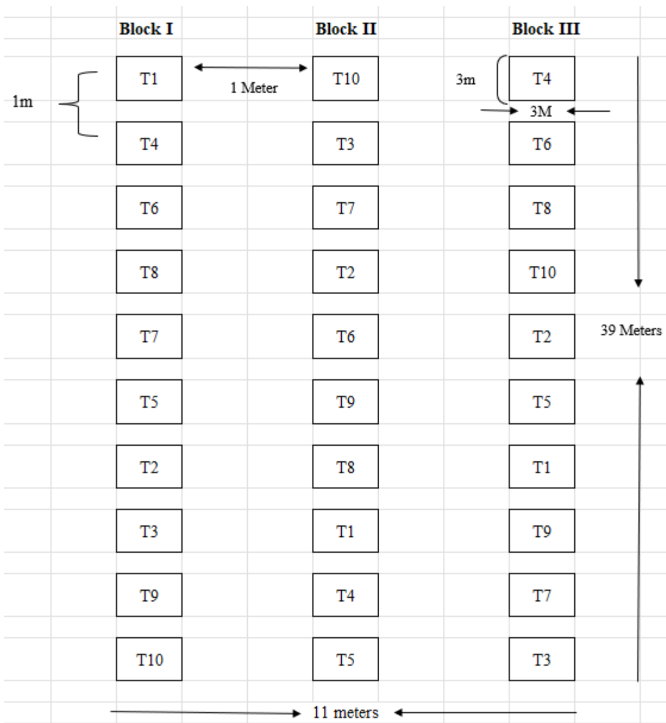
2.3 Respondents of the Study

The study did not involve human respondents, as it focused on experimental rice plants. The primary experimental units consisted of inbred rice variety NSIC Rc 222 grown under field conditions.

2.4 Sample and Sampling Procedure

The experimental field had a total area of 429.0 m², obtained from the overall dimensions of 39 m in length and 11 m in width. It was divided into three blocks and each block was further subdivided into ten plots measuring 3 m × 3 m, with 1.0 m alleys between plots and blocks. Ten sample plants were randomly selected from each plot for data collection. The layout of the experimental field followed a systematic arrangement, as illustrated in Figure 1, which shows the distribution of treatments across blocks and plots to ensure proper randomization and minimize bias. The treatments consisted of varying GA_3 concentrations and application timings. The concentrations ranged from 175,000 ppm to 250,000 ppm per hectare, with corresponding plot-level concentrations of 160 ppm, 180 ppm, 200 ppm, and 230 ppm. These were applied at different growth stages, including 20, 25, 40, 50, and 60 days after transplanting (DAT). As presented in Table 1, the combinations of GA_3 concentration and timing were structured to compare early and later applications and to determine optimal treatment conditions.

Figure 1: *The Experimental Layout of the study*



2.5 Research Instrument

The study utilized field measurement techniques and standard agronomic tools to collect growth and yield data. Plant height was measured from the base of the culm to the tip of the highest leaf at 30, 60, and 90 days after transplanting. The number of productive tillers was counted at maturity, while panicle length and culm length were measured using standard measuring tools. Spikelet fertility was determined by counting filled and unfilled grains and computing their ratio. Yield was calculated by weighing the grains of the sample plants after drying to 14% moisture content and converting the results to kilograms per hectare using a standard formula. These measurements provided quantitative data to assess the effects of GA_3 treatments on rice growth and productivity.

2.6 Data Gathering Procedure

The study began with the acquisition of materials, including NSIC Rc 222 seeds, fertilizers, pesticides, and GA_3. Soil samples were collected, processed, and analyzed at the Cagayan Valley Research Center to determine nutrient content and guide fertilizer application. Land preparation involved plowing, harrowing, leveling, and field conditioning under flooded conditions. Seedlings were produced through soaking, incubation, and broadcasting of pre-germinated seeds in prepared seedbeds. Proper care, including irrigation and fertilization, ensured vigorous seedling growth before transplanting at 21 days after sowing. GA_3 was applied at specified growth stages, particularly during booting and panicle heading, to evaluate the effects of timing. Different concentrations were diluted in water and applied uniformly across treatments. Fertilizer application followed soil analysis recommendations, while irrigation was managed through controlled flooding and alternate wetting and drying techniques. Weed and pest management practices included the use of herbicides, manual weeding, molluscicides, and insecticides to control weeds, golden apple snails, and insect pests. Harvesting was conducted manually at 101 days after transplanting, followed by threshing, drying, cleaning, and preparation of samples for analysis.

2.7 Data Analysis Techniques

The collected data were analyzed using Analysis of Variance (ANOVA) under the Randomized Complete Block Design (RCBD) to determine the significance of treatment effects and their interactions. The Statistical Tool for Agricultural Research (STAR) software was used for computation. To further identify differences among treatment means, Tukey's Honestly Significant Difference (HSD) Test was applied, allowing comparison of specific treatment combinations and determination of statistically significant differences.

3. Results and Discussion

3.1 Growth and Yield Performance of Inbred Rice under GA_3 Application

3.1.1 Plant Height at Different Growth Stages

At 30 days after transplanting (DAT), plant height across all treatments showed no significant differences, indicating uniform early growth regardless of GA_3 application. However, at 60 DAT, significant differences were observed, where GA_3-treated plants, particularly those applied at 25 and 50 DAT, exhibited markedly greater height compared to the controls. The tallest plants were observed under the 225,000 ppm treatment applied at 25 and 50 DAT, followed by similar treatments with slightly lower or higher concentrations. This trend continued up to 90 DAT, with GA_3-treated plants consistently maintaining greater height, while control treatments remained the shortest. These findings indicate that GA_3 significantly enhances plant height during later growth stages by promoting sustained elongation. This result aligns with previous studies showing that GA_3 stimulates cell elongation and internode expansion in rice. Asante et al. (2013) reported increased plant height due to GA_3-induced stem elongation, while Ramesh and Ramprasad (2015) observed greater vigor in treated plants. Moreover, Khan et al. (2009) emphasized the importance of proper timing, noting that plants respond more effectively during active vegetative growth. The present results confirm that GA_3 is most effective when applied at 25 and 50 DAT, leading to improved plant height.

3.1.2 Number of Productive Tillers

The number of productive tillers showed no significant differences among treatments, with values ranging from approximately 11.03 to 14.73. Control treatments recorded slightly higher tiller numbers compared to GA_3-treated plants, although the differences were minimal and not statistically significant. This suggests that GA_3 application does not significantly influence tiller production and may slightly reduce it in some cases. The findings are consistent with kabir et al. (2015), who reported that GA_3 primarily promotes stem elongation rather than tiller formation. Similarly, Verma and Singh (2017) explained that higher hormone levels may shift plant energy toward vertical growth instead of tiller production. Alam et al. (2010) further noted that tillering is more dependent on genetic and environmental factors than hormonal treatments. Thus, GA_3 mainly enhances plant height rather than increasing the number of productive tillers.

3.1.3 Length of Panicle

Panicle length did not differ significantly among treatments, with values ranging from 22.67 cm to 26.47 cm. Control treatments produced some of the longest panicles, while several GA_3-treated plants, especially at higher concentrations, exhibited slightly shorter panicles. This indicates that GA_3application does not improve panicle length and may slightly reduce it under certain conditions. These findings are consistent with Islam et al. (2017) and Pradhan et al. (2019), who reported that GA_3 enhances vegetative growth but has limited effects on reproductive traits such as panicle length. Singh and Chaurasia (2020) also noted that excessive GA_3 may redirect plant energy toward height growth rather than reproductive development. Additionally, Zhang et al. (2021) emphasized that panicle length is largely genetically controlled and less responsive to hormonal treatments. Therefore, panicle development appears to be more influenced by inherent plant characteristics than GA_3 application.

3.1.4 Culm Length

Culm length showed significant differences among treatments, with GA_3-treated plants exhibiting longer culms compared to the controls. The longest culm was observed in plants treated with 225,000 ppm applied at 25 and 50 DAT, followed by treatments with similar timing and varying concentrations. Control treatments recorded the shortest culm lengths. These results demonstrate that GA_3 significantly enhances culm elongation, particularly when applied during mid-growth stages. This agrees with Rahman et al. (2018), who found that GA_3 promotes internode elongation through cell expansion. Li et al. (2020) and Nguyen et al. (2021) also reported increased stem growth when $GA_3$is applied during active vegetative stages. Sharma and Singh (2019) further highlighted that higher GA_3 doses enhance culm elongation, although excessive growth may increase lodging risk. The findings confirm that both timing and concentration are critical factors influencing culm development.

3.2 Yield Components of Inbred Rice

3.2.1 Number of Filled Grains

The number of filled grains per panicle showed no significant differences among treatments, although values varied widely from approximately 47.43 to 71.60. Some GA_3-treated plants, particularly those applied at 25 and 50 DAT, produced fewer filled grains compared to the controls, while others showed comparable values. This suggests that GA_3 does not significantly improve grain filling and may reduce it under certain conditions. Kumar et al. (2017) and Zafar et al. (2019) reported that excessive GA_3 may divert energy toward vegetative growth rather than reproductive processes, leading to reduced grain filling. Chen et al. (2020) emphasized that grain filling is strongly influenced by factors such as nutrient availability and genetic traits. Similarly, Rahman et al. (2021) found that GA_3 increases plant height without consistently improving grain number. These findings indicate that grain filling is largely governed by inherent plant and environmental factors rather than GA_3 application.

3.2.2 Grain Yield per Net Plot

Grain yield per net plot did not show significant differences among treatments, although numerical variations were observed. The highest yield was recorded in one of the GA_3-treated plots, closely followed by a control treatment and several other GA_3 treatments. The lowest yield was observed in a treatment with higher GA_3concentration applied at multiple intervals. These results indicate that GA_3does not significantly enhance grain yield despite slight numerical differences. This supports the findings of Pradhan et al. (2019) and Zafar et al. (2020), who reported that GA_3 may increase vegetative growth without improving yield. Zhang et al. (2021) explained that increased energy allocation to stem elongation may reduce resources available for grain development. Rahman et al. (2022) also noted that high GA_3 concentrations or improper timing can negatively affect yield. Thus, GA_3application does not guarantee higher grain production.

3.2.3 Computed Grain Yield per Hectare

Computed grain yield per hectare also showed no significant differences among treatments, although values ranged from approximately 5.70 to 7.31 t/ha. The highest yield was recorded in a GA_3-treated plot, followed closely by a control treatment and other treatments with similar values. Lower yields were observed in treatments with higher concentrations applied at specific timings. These findings confirm that GA_3 application does not significantly influence overall grain yield. The results are consistent with Pradhan et al. (2019) and Zafar et al. (2020), who found that GA_3 primarily promotes vegetative growth rather than reproductive performance. Zhang et al. (2021) reported that excessive GA_3 may reduce yield by diverting nutrients to stem elongation. Rahman et al. (2022) further explained that improper GA_3 application can increase lodging risk and reduce grain filling. Overall, the results indicate that natural growth conditions were sufficient for optimal yield, and GA_3 application did not provide additional benefits.

4. Conclusion & Recommendations

The study demonstrated that varying rates and timing of Gibberellic acid 3 (GA_3) application significantly influenced the vegetative growth of inbred rice, particularly in increasing plant height and culm length, especially when applied at mid-season stages. However, GA_3 application did not significantly affect key yield components such as number of productive tillers, panicle length, number of filled grains, grain yield per plot, and computed yield per hectare. In some cases, higher concentrations and specific application timings resulted in reduced grain filling and lower yields. Overall, the results indicate that while GA_3 enhances vegetative growth, it does not improve reproductive performance or grain yield and may negatively affect productivity under the conditions tested.

It is recommended that the use of GA_3 at 10% purity in inbred rice production be minimized, as the tested rates and application timings did not improve yield and, in some instances, reduced productivity. Application of high concentrations and mid-season treatments should be avoided since they primarily promote vegetative growth without enhancing yield components. Further studies are recommended to evaluate lower concentrations, alternative application timings, and integration with other agronomic practices, as well as to conduct site-specific trials under varying environmental conditions. Maintaining standard rice production practices without GA_3 application is suggested as a more effective approach for maximizing yield.

The study was limited to a single inbred rice variety and was conducted within a specific location and growing season, which may influence the generalizability of the results. The evaluation was restricted to selected rates and timing of GA_3 application, and other possible combinations or environmental interactions were not explored. Additionally, variability in environmental conditions and field factors may have influenced the observed results, limiting the extent to which the findings can be applied to different settings.

Compliance with ethical standards

The authors declare no conflict of interest and confirm that this study received no external funding. The research was conducted at Magassi, Cabagan, Isabela under the supervision of the academic institution, with the cooperation of individuals involved in field implementation, whose participation was voluntary and based on informed consent. Data were collected through non-invasive field methods during the conduct of the rice experiment, and all information was handled with strict confidentiality, ensuring that no identifying details were disclosed.

REFERENCES

Bokade, N., Bhalekar, M., Gupta, N., & Deshpande, A. (2006). Effect of growth regulators on growth and yield of tomato in summer. *Journal of Maharashtra Agricultural Universities, 31*(1), 64–65.

Britannica, T. Editors of Encyclopaedia. (2024). Rice. *Encyclopedia Britannica*. https://www.britannica.com/plant/rice

Chaudhary, B., Sharma, M., Shakya, S., & Gautam, D. (2006). Effect of plant growth regulators on growth, yield, and quality of chilli (*Capsicum annuum* L.) at Rampur, Chitwan. *Journal of Institute of Agriculture and Animal Science, 27*, 65–68.

Dunand, R. (1993). *Gibberellic acid seed treatment in rice* (p. 510). LSU Agricultural Experiment Station Reports.

Gabal, G., Oben, G., & Garcell, R. (1999). Effect of GA on morph physiological characters and yield of kidney beans (*Phaseolus vulgaris*). *Journal of Agronomy and Crop Science, 160*(2), 91–101.

Gavino, R., Pi, Y., & Abon Jr., C. C. (2008). Application of gibberellic acid (GA_3) in dosage for three hybrid rice seed production in the Philippines. www.thaiscience.info

Gelmesa, D., Abebie, B., & Lemma, D. (2012). Regulation of tomato (*Lycopersicum esculentum* Mill.) fruit setting and earliness by gibberellic acid and 2,4-dichlorophenoxy acetic acid application. *African Journal of Biotechnology, 11*(51), 11200–11206.

Gemici, M., Guve, A., & Yurekli, A. (2000). Effect of some growth regulators and commercial preparations on the chlorophyll content and mineral nutrition of *Lycopersicum esculentum* Mill. *Turkish Journal of Botany, 24*, 215–219.

HG. Haifa Group. (2024). Crop guide: Rice cultivation. Retrieved from https://www.haifa-group.com/rice-fertilizer/crop-guide-rice-cultivation

Hasanuzzaman, A., Md-Mazed, K., Ashraful, I., Md, P., Chowdhury, M., & Moonmoon, J. (2015). *International Journal of Applied Research, 1*(3), 71–74.

Hedden, P., & Phillips, A. (2000). Gibberellin metabolism: New insights revealed by the genes. *Trends in Plant Science, 5*(12), 523–530.

Heden, P., & Thomas, S. (2012). Gibberellin biosynthesis and its regulation. *The Biochemical Journal, 444*(1), 11–25.

Hossain, S., Sarker, C., & Mahmud, S. (2019). Effect of plant growth regulator on the growth and high yield of heat tolerant tomato variety (*Lycopersicum esculentum* Mill). *American Journal of Pure and Applied Science, 1*(5), 30–43.

Iqbal, N., Nazar, R., Khan, M., Masood, A., & Khan, N. (2011). Role of gibberellins in regulation of source–sink relations under optimal and limiting environmental conditions. *Current Science*, 998–1007.

Islam, M. (1995). Seed production studies on bitter gourd (*Momordica charantia*). *Seed Science, 33*, 121–123.

Khan, M., Gautam, A., Mohammad, F., Siddiqui, M., Naeem, M., & Khan, M. (2006). Effect of gibberellic acid spray on performance of tomato. *Turkish Journal of Biology, 30*, 11–16.

Khadija, M., Ismail, M., Hakim, M., Musa, M., & Adam, P. (2013). Effect of salinity and alleviating role of gibberellic acid (GA_3) for improving the morphological, physiological and yield traits of rice varieties. *Australian Journal of Crop Science, 7*(11), 1682–1692.

Krishnamurthy, K. (2015). *Growth and development in plants (Textbook series: 21st century biology and agriculture)*. Scientific Publishers.

Liu, Y., Chen, W., Ding, Y., Wang, Q., Li, G., & Wang, S. (2012). Effect of gibberellic acid (GA_3) and α-naphthalene acetic acid (NAA) on the growth of unproductive tillers and the grain yield of rice (*Oryza sativa* L.). *African Journal of Agricultural Research, 7*, 534–539.

Ma, G., & Yuan, L. (2015). Hybrid rice achievements, development and prospect in China. *Journal of Integrative Agriculture, 14*(2), 197–205. https://doi.org/10.1016/s2095-3119(14)60922-9

Melissa, F., & Nina, M. (2005). Effects of naphthaleneacetic acid (NAA) and gibberellic acid (GA_3) on fruit morphology, parthenocarpy, alkaloid and chlorophyll content in bitter gourd (*Momordica charantia* L. 'Makiling'). *Philippine Agricultural Scientist, 88*, 35–39.

Mostafa, E., & Saleh, M. (2006). Influence of spraying with gibberellic acid on the behavior of Anna apple trees. *Journal of Applied Sciences Research, 2*, 477–483.

Naeem, N., Ishtiaq, M., Khan, P., Mohammad, N., Khan, J., & Jamiher, B. (2001). Effect of gibberellic acid on growth and yield of tomato cv. Roma. *Journal of Biological Sciences, 1*(6), 448–450.

Nibhavanti, B., Bhalekar, M., Gupta, N., & Deshpande, A. (2006). Effect of growth regulators on growth and yield of tomato in summer. *Journal of Maharashtra Agricultural Universities, 31*(1), 64–65.

Ozguven, A., Yilmaz, C., Hietaranta, T., & Linna, M. (2000). The effect of GA_3 and promalin on fruit quality of strawberry. *Acta Horticulturae, 548*, 216–219.

Park, T. (2020). Kendall Reagan Nutrition Center: Is rice good for you? Retrieved from https://www.chhs.colostate.edu/krnc/monthly-blog/is-rice-good-for-you

Peng, S. (2014). Reflection on China's rice production strategies during the transition period. *Zhongguo Kexue Shengming Kexue, 44*(8), 845–850. https://doi.org/10.1360/052014-98

Pepi, N., Surahman, M., Purwoko, S., Tatiek, & Suharsi, K. (2014). Effect of GA_3 concentration on hybrid rice seed production in Indonesia. *International Journal of Applied Science and Technology, 4*, 23.

PhilRice. (2018). National rice R&D highlights. Retrieved from https://www.philrice.gov.ph/wp-content/uploads/2020/11/CPD.pdf

PhilRice. (2023). Retrieved from https://www.philrice.gov.ph/ricelytics/productions/province/31

PNA. (2024). DA assures stable rice supply in 2024 despite production decline in Q1. Retrieved from https://www.pna.gov.ph/articles/1223917

Ponnuswamy, A., & Prabagaran, S. (1997). A sustainable substitute to gibberellic acid for hybrid rice seed production. *Madras Journal of Agricultural Science, 84*(7), 384–385.

Prasad, R., Singh, S., Yadava, R., & Chaurasia, S. (2013). Effect of GA_3 and NAA on growth and yield of tomato. *Vegetable Science, 40*(2), 195–197.

PSA. (2024). Palay situation report, January to December 2023. Retrieved from https://psa.gov.ph/content/palay-situation-report-january-december-2023

Pundir, J., & Yadav, P. (2001). Effect of GA_3, NAA, and 2,4-D on growth, yield and quality of tomato var. Punjab Chhuhara. *Current Agriculture, 25*, 1–2.

RH. (2024). RICEHUB: The rice plant. Retrieved from http://www.ricehub.org/RT/crop-establishment/-the-rice-plant/

Rahman, M., Haque, M., & Mostofa, M. (2015). Effect of GA_3on biochemical attributes and yield of summer tomato. *Journal of Bioscience and Agriculture Research, 3*(02), 73–78.

Ramesh, K., Singh, V., Meena, R., & Kumar, S. (2019). Effect of gibberellic acid on growth, yield and quality of rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry, 8*(6), 2886–2890.

Ramesh, S., Sudhakar, P., Elankavi, S., Suseendran, K., & Jawahar, S. (2019). Effect of gibberellic acid (GA_3) on growth and yield of rice (*Oryza sativa* L.). https://www.plantarchives.org/

Sabagh, A., Mbarki, S., Hossain, A., Iqbal, M., Islam, M., Raza, A., Llanes, A., Reginato, M., Rahman, M., Mahboob, W., Singhal, R., Kumari, A., Rajendran, K., Wasaya, A., Javed, T., Shabbir, R., Rahim, J., Barutçular, C., Rahman, M., & Farooq, M. (2021). Potential role of plant growth regulators in administering crucial processes against abiotic stresses. *Frontiers in Agronomy, 3*. https://doi.org/10.3389/fagro.2021.648694

Sakamoto, T., Kobayashi, M., Itoh, H., Tagiri, A., Kayano, T., Tanaka, H., & Matsuoka, M. (2004). Expression of a gibberellin 2-oxidase gene around the shoot apex is related to phase transition in rice. *Plant Physiology, 134*(2), 1474–1482.

Sarkar, S., Khatun, S., & Sarkar, B. (2002). Effects of plant growth substances on growth, yield and quality of soybean. *Bangladesh Journal of Botany, 31*(2), 91–94.

Stowe, B., & Yamaki, T. (1957). The history and physiological action of the gibberellins. *Annual Reviews*. https://doi.org/10.1146/annurev.pp.08.060157.001145

Stuecker, M., Tigchelaar, M., & Kantar, M. (2018). Climate variability impacts on rice production in the Philippines. *PLOS ONE, 13*(8), e0201426.

Sukifto, R., Nulit, R., Kong, Y., Sidek, N., Mahadi, S., Mustafa, N., & Razak, R. (2020). Enhancing germination and early seedling growth of Malaysian indica rice (*Oryza sativa* L.) using hormonal priming with gibberellic acid (GA_3). *AIMS Agriculture & Food, 5*(4), 649–665. https://doi.org/10.3934/agrfood.2020.4.649

Sultana, M. (2013). *Effect of nitrogen and gibberellic acid on growth and yield of tomato* (Master's thesis, Sher-e-Bangla Agricultural University, Dhaka).

Sun, T. (2004). Gibberellin metabolism, perception and signaling pathways in *Arabidopsis*. *The Arabidopsis Book, 2*, e0078.

Thu, B., Chakrabarty, S., Sharma, S., & Dadlani, M. (2008). Studies on environmental conditions and pollination management in hybrid rice seed production. *Indian Journal of Genetics and Plant Breeding, 68*(04), 426–434.

Tiwari, S., Lata, C., Chauhan, P., Prasad, V., & Prasad, M. (2011). A functional genomic perspective on drought signalling and its crosstalk with phytohormone-mediated signalling pathways in plants. *Current Genomics, 12*(5), 333–343.

USDA ERS. (2023). Rice sector at a glance. Retrieved from https://www.ers.usda.gov/topics/crops/rice/rice-sector-at-a-glance/

Wang, X., Zheng, H., Tang, Q., Mo, W., & Ma, J. (2019). Effects of gibberellic acid application after anthesis on seed vigor of indica hybrid rice (*Oryza sativa* L.). *Agronomy, 9*(12), 861.

Yamaguchi, S. (2008). Gibberellin metabolism and its regulation. *Annual Review of Plant Biology*. https://doi.org/10.1146/annurev.arplant.59.032607.092804

Zhou, H., Li, P., Xie, W., Hussain, S., Li, Y., Xia, D., & He, Y. (2017). Genome-wide association analyses reveal the genetic basis of stigma exsertion in rice. *Molecular Plant, 10*(4), 634–64.