

The Effect of Soaking Medium Type on the Viability, Vigor, and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

Dewa Gede Suarjaya¹, I Nyoman Rai², Ni Nyoman Ari Mayadewi³

¹ Student of Master Program in Dryland Agriculture, Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia

^{2,3} Agronomy and Horticulture Laboratory, Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia

ABSTRACT: Arabica coffee seeds have a relatively slow germination process due to their hard seed coat, which is not very permeable to water, thereby hindering the production of high-quality seedlings. This study aimed to analyze the effects of several soaking treatments on the viability, vigor, germination, and early growth of Arabica coffee seeds (*Coffea arabica* L.). The study used a one-factor randomized block design consisting of three treatments: soaking in water (B0), 50% coconut water (B1), and Golden Grow at a concentration of 2 mL L⁻¹ (B2). Each treatment was replicated three times. The seeds were soaked for four hours before germination. The data were analyzed using analysis of variance (ANOVA) followed by the Least Significant Difference (LSD) test at the 5% significance level. The results showed that the soaking treatments had a significant to highly significant effect on germination rate, maximum growth potential, growth rate, basal diameter, hypocotyl length, number of secondary roots, cotyledon length, and cotyledon color, but had no significant effect on growth uniformity and vigor index. Soaking with Golden Grow resulted in the highest germination rate and maximum growth potential, at 100% each, as well as a growth rate of 8.24% etmal⁻¹. This treatment also produced a basal diameter of 1.94 mm, a hypocotyl length of 8.51 cm, 9.07 secondary roots, a cotyledon length of 4.72 cm, and a cotyledon color score of 3.33. Therefore, soaking seeds in Golden Grow can be recommended as an effective pre-planting treatment to improve the viability, vigor, and early growth of Arabica coffee seeds.

KEYWORDS: Arabica coffee, coconut water, Golden Grow, seed germination, seed soaking, seed vigor

INTRODUCTION

Arabica Coffee Arabica coffee (*Coffea arabica* L.) is one of the agricultural commodities widely cultivated by farmers in the highlands of Bali Province. Arabica coffee is a high-value export commodity that is currently in high demand in the market due to its distinctive flavor and aroma, making it a favorite among coffee connoisseurs. The area under Arabica coffee cultivation in Bali Province in 2024 reached 11,537 ha, with a production of 3,785 metric tons. This production volume has not yet been sufficient to fully meet market demand, which continues to rise. On the other hand, Arabica coffee production has declined over the past five years, from 4,189 metric tons in 2020 to 3,785 metric tons in 2024 (Bali Provincial Central Statistics Agency, 2025). One factor contributing to the decline in Arabica coffee production is the advanced age of the plants, which leads to reduced productivity. Arabica coffee plants generally have a productive lifespan of up to about 20 years (Directorate General of Plantations, 2023). According to data from the Bali Provincial Department of Agriculture and Food Security (2024), the area of non-productive Arabica coffee plantations totals 772.81 ha. These two conditions have prompted the government and farmers to pursue the development of Arabica coffee areas, whether by replacing old plants through replanting or by increasing the area of Arabica coffee plantations through expansion. Both replanting and expansion require high-quality seeds that possess high viability and vigor and are well-adapted to their growing environment.

Arabica coffee plants are generally propagated generatively using seeds. This is because Arabica coffee is self-pollinating, so the resulting seeds have genetic traits that are nearly identical to those of their parent plants. However, the process of producing seeds and preparing them for distribution often faces obstacles, one of which is that Arabica coffee seeds belong to the intermediate seed group, which is prone to quality degradation under unsuitable storage conditions. This decline in seed quality can lead to reduced seed viability and vigor during storage (Gebeyehu, 2020). Additionally, Arabica coffee seeds have a dormancy period and a relatively slow germination process. Arabica coffee seeds take about 6–8 weeks to germinate under normal

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

conditions (Armalia *et al.*, 2024). The length of the germination period can hinder the provision of the large quantities of seedlings needed to support the replanting and expansion of Arabica coffee plantations.

One method that can be used to accelerate the germination of Arabica coffee seeds is seed soaking. Soaking the seeds can help speed up the water imbibition process, soften the seed coat, activate early metabolism, and stimulate the germination process. Farmers generally soak seeds in plain water, but plain water only helps soften the seed coat and does not provide growth-promoting compounds that can support optimal germination. Using a seed soaking solution containing nutrients, amino acids, or bioactive compounds is an effective option because it not only accelerates early physiological processes but also supplies essential elements needed during the germination phase and early root formation. Seed soaking agents that can be used to optimize seed germination include coconut water and Golden Grow. Coconut water is a natural substance with great potential for use because it contains growth hormones such as auxin and cytokinin, which play a role in stimulating cell division and elongation. Research by Nurhaliza *et al.* (2022) also showed that soaking coffee seeds in 50 % coconut water for 4 hours had a significant effect on germination rate, growth rate, hypocotyl length, dry weight of seedlings, and seed vigor. Meanwhile, Golden Grow also has potential for use as a germination stimulant because it contains IBA (Indole-3-Butyric Acid), which belongs to the auxin hormone group. Auxins play a role in stimulating cell elongation, root formation, and early plant growth. Murni *et al.* (2025) stated that soaking corn seeds in Golden Grow can increase the germination rate compared to the soaking method commonly used by farmers.

Based on the above discussion, seed soaking treatments using coconut water and Golden Grow are believed to enhance the germination of Arabica coffee seeds. However, the effectiveness of these two materials on Arabica coffee seed germination is still very limited and requires further study. Therefore, this study aims to analyze the effects of several seed soaking treatments on Arabica coffee seed germination.

RESEARCH METHODOLOGY

Research Location and Time

A study on the germination of Arabica coffee seeds was conducted at the Plant Breeding and Seed Technology Laboratory of the Faculty of Agriculture at Udayana University from August through October 2025.

Materials and Equipment

The materials required were Kopyol variety Arabica coffee seeds (a high-yielding Arabica coffee variety native to Bali), rice straw paper, Golden Grow fertilizer, and young coconut water (from 6- to 7-month-old coconuts). The equipment used in this study included boxes, rice straw paper, measuring cups, a sprayer, a germinator, a ruler/measuring tape, a vernier caliper, a leaf color chart, and a microscope.

Experimental Design

This study used a one-factor randomized block design (RBD) consisting of three levels, namely :

- B0 = Soaking seeds in water
- B1 = Soaking the seeds in coconut water at a 50% concentration
- B2 = Seed soaking using Golden Grow at a concentration of 2 ml L⁻¹

Each treatment was repeated three times, resulting in 9 experimental units.

Research Implementation

The coffee seeds used in the study were prepared and divided into three groups according to the seed soaking treatments: B0, B1, and B2. The Arabica coffee seeds were soaked for 4 hours. After the soaking process was complete, the seeds were drained and sown in trays labeled with the treatment codes. Each tray contained 25 seeds that had been arranged and were then placed in a germinator. The seeds were watered every two days or when the growing medium was no longer moist.

Observation Variables

The variables observed in the germination of Arabica coffee seeds are as follows :

1. Maximum Growth Potential (%). Observations were conducted until the seeds were 49 days old after sowing by counting normal and abnormal seedlings
2. Germination Rate (%). Observations were conducted when the seeds were 25 and 49 days old after sowing by counting normal seedlings.
3. Seedling Growth Rate (% etmal⁻¹). Observations were conducted daily by counting the number of normal seedlings per unit of time.

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

4. Seed Germination Uniformity (%). Observations were conducted when the seeds were 37 days after sowing by counting the number of strong, normal seedlings.
5. Vigor Index (%). Observations were made by counting the number of normal seedlings at 25 days after sowing.
6. Basal diameter (mm). Measurements were taken 1 cm from the base of the hypocotyl during the final observation (49 days after sowing).
7. Hypocotyl Length (cm). Measurements were taken when the seeds were 49 days after sowing.
8. Number of roots. The number of roots was counted during the last observation.
9. Presence of root hairs. Observations were made using a microscope to examine the condition of the root hairs.
10. Length seed leaf/cotyledon. Measurements were taken when the seedlings were 49 days by measuring the two tips of the seed leaf/cotyledons.
11. Color of seed leaf/cotyledon. The results were obtained by comparing the seed leaf/cotyledons with the colors on the leaf color chart.

Data Analysis

The research data were analyzed using analysis of variance (ANOVA) to determine the effect of the treatments on the observed variables. If the analysis results indicated a significant effect, the Least Significant Difference (LSD) test was then conducted at the 5% significance level to determine differences in results among the treatments.

RESULTS

Significance of the Effect of Treatment on the Research Variables

Based on the results of the significance analysis in Table 5.1, seed soaking had a significant to highly significant effect on most variables related to Arabica coffee seed germination, namely germination capacity, maximum growth potential, seed growth rate, hypocotyl length, basal diameter, number of secondary roots, cotyledon length, and cotyledon color. Seed soaking was also found to have no significant effect on seed growth uniformity and seed vigor index.

Table 1. Significance of the Effect of Soaking Treatment on Arabica Coffee Seeds

No	Observation Variables	Significance
1	Germination Rate (%)	*
2	Maximum Growth Potential (%)	*
3	Seed Growth Rate (% etmal ⁻¹)	*
4	Germination Uniformity (%)	ns
5	Vigor Index (%)	ns
6	Basal Diameter (mm)	**
7	Hypocotyl Length (cm)	*
8	Number of Secondary Roots	**
9	Length Seed Leaf	**
10	Color of Seed Leaf	**

Notes: ns: not significant, *: significant, **: highly significant.

Seed Viability and Vigor

The results of the analysis in Table 2 show that the treatment yielding the highest germination rate was seed soaking with Golden Grow (B2) at 100%, while the lowest was treatment B0 with a germination rate of 92%. The analysis revealed that the average germination rate of seeds in treatment B2 differed significantly from that in treatments B0 and B1. Applying treatment B2 to Arabica coffee seeds increased the germination rate by 8% compared to B0. The high germination rate in treatment B2 was also accompanied by the highest values for other seed viability and vigor variables, namely maximum growth potential (100%), seed growth rate (8.24), seed growth uniformity (90.67%), and vigor index (90.67%). Meanwhile, the seed soaking treatment with water (B0) consistently yielded the lowest results for the viability and vigor variables of Arabica coffee seeds.

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

Table 2. The Effect of Seed Soaking Treatments on Seed Vigor and Viability

Seed Soaking Treatment (B)	Germination Rate (%)	Maximum Growth Potential (%)	Seed Growth Rate (%/etmal)	Germination Uniformity (%)	Vigor Index (%)
B0	92.00 b	96.00 b	6.42 b	80.00 a	76.00 a
B1	93.33 b	98.67 ab	8.21 a	88.00 a	88.00 a
B2	100.00 a	100.00 a	8.24 a	90.67 a	90.67 a
LSD 5 %	6.05	3.02	1.44	12.09	23.61

Notes : Numbers followed by the same letter in the same column in the seed soaking treatment show no significant difference in the 5% level of the least significant difference test (BNT).

Seed Germination

The seed soaking treatment with Golden Grow (B2) yielded early growth results that were significantly different from those of the seed soaking treatment with water. Table 3 shows that treatment B2 yielded the highest results for all seed germination variables, namely a basal diameter of 1.94 mm, a hypocotyl length of 8.51 cm, 9.07 secondary roots, length seed leaf/cotyledon of 4.72 cm, and seed leaf/cotyledon color score of 3.33. Based on the Least Significant Difference (LSD) test at the 5% level, the germination results from the seed soaking treatments with Golden Grow (B2) and coconut water (B1) were not statistically significantly different. The lowest germination rate occurred in the seed soaking treatment with water (B0); this result differed significantly from the germination rates in treatments B2 and B1.

Table 3. The Effect of Seed Soaking Treatments on the Germination of Arabica Coffee Seeds

Seed Soaking Treatment (B)	Basal Diameter (mm)	Hypocotyl Length (cm)	Number of Secondary Roots	Length Seed Leaf/ Cotyledon (cm)	Color of Seed Leaf/Cotyledon
B0	1.68 b	7.51 b	5.63 b	4.06 b	1.17 b
B1	1.98 a	8.42 a	9.00 a	4.64 a	2.83 a
B2	1.94 a	8.51 a	9.07 a	4.72 a	3.33 a
LSD 5 %	0.12	0.61	0.75	0.15	0.76

Notes : Numbers followed by the same letter in the same column in the seed soaking treatment show no significant difference in the 5% level of the least significant difference test (BNT).

In addition to the variables mentioned above, this study also examined the effect of seed soaking on the presence of root hairs in each treatment, as observed under a microscope. The number of root hairs can serve as an indicator supporting seed viability and vigor, as the presence of root hairs indicates that the seed's initial physiological processes are proceeding optimally and play a crucial role in the absorption of water and nutrients from the growing medium. The results of the microscopic observations of Arabica coffee seed root hairs are shown in Figure 1.

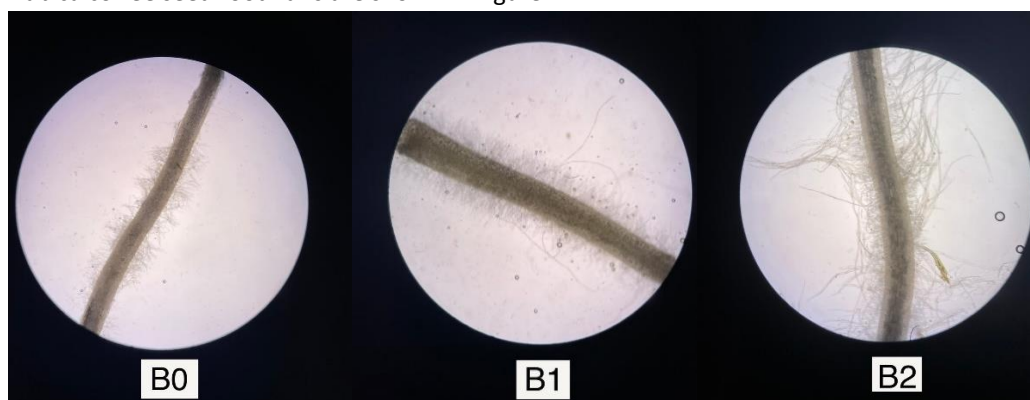


Figure 1. Results of microscopic observations of the root hairs of Arabica coffee seeds 49 days after sowing for each treatment, viewed under a microscope at 10x magnification

Figure 1 shows that the root hairs in the seed soaking treatment with water (B0) were shorter and fewer in number. This indicates that in the B0 treatment, root hair growth was still very limited and reflected the lowest seed viability and vigor among the other treatments. The coconut water soaking treatment (B1) resulted in a greater number of root hairs that were longer than

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

those in the B0 treatment and were evenly distributed throughout the root. This indicates that treatment B1 for Arabica coffee seeds enhances seed vigor and physiological activity compared to treatment B0. Meanwhile, Arabica coffee seeds soaked in Golden Grow (B2) exhibited the highest number of root hairs and the longest root hairs compared to the other two treatments. This proves that treatment B2 resulted in the greatest increase in root hair growth compared to treatments B0 and B1.

DISCUSSION

The research results indicate that seed soaking had a significant to highly significant effect on most variables related to germination, viability, and vigor of Arabica coffee seeds, except for seed germination uniformity and the vigor index, for which the effect was not significant (Table 1). These results confirm that soaking seeds with germination stimulants plays a crucial role in overcoming physiological dormancy caused by the hard structure of Arabica coffee bean hulls, which are not very permeable to water.

Soaking seeds in Golden Grow (B2) consistently yielded the highest values for nearly all observed parameters, with a germination rate of 100%, which was significantly different from the seed soaking treatment using water (B0) at 92%, but not significantly different from the seed soaking treatment using coconut water (B1) at 93.33%. The best germination rate observed in treatment B2 is likely due to the auxin content in Golden Grow, which plays a role in stimulating cell elongation and division during the early phase of embryo activation, thereby accelerating the imbibition process in seeds with hard seed coats. These results are also supported by the findings of Putra *et al.* (2012), who reported that seed soaking treatments can accelerate the imbibition process in Arabica coffee seeds, which have a hard seed coat.

The high germination rate observed in treatment B2 was consistent with the variables of maximum growth potential, seed growth rate, seed growth uniformity, and vigor index. This indicates that the effect of Golden Grow is not limited to the initiation of germination but also extends to improving the physiological quality of the resulting seedlings. The germination rate value, which matched the maximum growth potential in treatment B2, indicates that all germinated seeds grew normally without any abnormal sprouts. This finding is consistent with the results of a study by Murni *et al.* (2025), which stated that soaking corn seeds in Golden Grow containing 0.85% Indole-3-Butyric Acid (IBA) resulted in a higher percentage of normally germinated seeds compared to farmers' conventional methods. Treatment B2 also showed the highest seed growth rate, at 8.24 % etmal⁻¹. A higher seed growth rate indicates that the seeds are not only capable of germinating but also have a faster germination rate. Rapid seed germination increases the likelihood of uniform seedling growth and reduces the risk of seed damage caused by environmental factors. The significant difference in seed growth rates between treatments B2 and B1 compared to B0 demonstrates that soaking seeds in a germination stimulant containing growth hormones stimulates growth and accelerates physiological processes in the seeds, particularly water uptake, enzyme activity, and the efficient utilization of seed food reserves.

During the seedling growth stage, treatment B2 yielded the highest values for basal diameter, hypocotyl length, number of secondary roots, cotyledon length, and cotyledon color score, although these differences were not statistically significant compared to treatment B1 for most of these variables (Table 3). Both Golden Grow and coconut water are known to contain the endogenous hormone auxin, which plays a role in regulating cambium cell division and promoting phloem and xylem differentiation, mechanisms that directly contribute to basal diameter thickening (Hidayati and Subroto, 2018). In addition, auxin also plays a role in regulating hypocotyl elongation through two complementary mechanisms: activation of the transcriptional response via Auxin Response Factors (ARFs) and modulation of apoplastic pH to support cell wall softening and expansion (Wang *et al.*, 2025; Reed *et al.*, 2018). The role of auxin in treatments B1 and B2 resulted in significant differences in hypocotyl length between treatment B0 and treatments B1 and B2. This is also consistent with the findings of Adibah *et al.* (2025), who reported that seed priming with auxin increased the hypocotyl length of seedlings in proportion to the applied concentration.

Based on the research results, treatment B2 produced the highest number of secondary roots, while treatment B1 produced the longest radicle. This indicates that treatment B1 is more effective at promoting primary root (radicle) elongation. The difference in the effects of treatments B2 and B1 indicates a functional trade-off in root system architecture, whereby the auxin contained in Golden Grow appears to direct hormonal signals toward lateral root initiation and secondary root branching, whereas coconut water, which is rich in a broader spectrum of natural phytohormones and nitrogen compounds, tends to support the axial elongation of the primary root. Both of these root development strategies are regulated by auxin, which plays a central role in regulating primary root meristem activity, root elongation, and lateral root formation (Roychoudhry and Kepinski, 2022).

Microscopic observations of root hairs showed that seedlings in treatment B0 had shorter root hairs in smaller numbers, reflecting limited physiological activity and the lowest vigor among all treatments. In contrast, treatment B1 produced more and longer root hairs that were evenly distributed throughout the root, while treatment B2 produced the highest number and length

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

of root hairs among all treatments (Figure 2). Root hairs are extensions of epidermal cells that play a crucial role in water and nutrient uptake; the better development of root hairs in treatments B1 and B2 indicates that the seedlings in these two treatments are physiologically better prepared to absorb water and nutrients from the growing medium immediately after germination. However, the effect of auxin on root architecture is concentration-specific; at excessively high concentrations, auxin can actually inhibit lateral root formation (Alarcon *et al.*, 2019).

Soaking the seeds in a germination stimulant also affected cotyledon growth. Well-developed cotyledons indicate that metabolic processes within the seed such as water absorption, enzyme activation, and the utilization of food reserves—are more optimal. Treatment B2 yielded the best cotyledon growth, with a cotyledon length of 4.72 cm and seed leaf/cotyledon color score of 3.33, which differed significantly from the cotyledon growth results in treatment B0 but did not differ significantly from those in treatment B1. This demonstrates that soaking seeds using germination stimulants such as Golden Grow and coconut water can improve the quality of early seedling growth in Arabica coffee seeds. Soaking seeds with germination stimulants produces cotyledons that are green and fresh, with higher chlorophyll content. This is because Golden Grow and coconut water contain auxin hormones, which play a crucial role in enhancing cell division and differentiation in the embryo, thereby accelerating the growth and development of cotyledons. These results are consistent with the study by Li *et al.* (2024), in which seed soaking with IBA increased chlorophyll content during the early growth phase by enhancing physiological seed development and maintaining photosynthetic activity in young tissues.

Overall, the consistent results for seed viability, vigor, and germination indicate that soaking seeds in a germination-promoting solution, particularly Golden Grow, effectively improves the physiological quality of Arabica coffee seeds. These improvements are attributed to the auxin content in Golden Grow and coconut water, which together promote cell division, cell elongation, and root system development during the crucial early stages of seedling formation.

CONCLUSION

Seed soaking treatment had a significant to highly significant effect on most variables related to germination, viability, vigor, and early growth of Arabica coffee seeds, except for seed growth uniformity and the vigor index, for which the effect was not significant. Soaking the seeds with Golden Grow was the most effective treatment, resulting in the highest germination rate (100%), the highest maximum growth potential (100 %), the highest seed growth rate (8.24 % etmal⁻¹), and the best morphological characteristics of the seedlings, including basal diameter (1.94 mm), hypocotyl length (8.51 cm), number of secondary roots (9.07), cotyledon length (4.72 cm), and cotyledon color score (3.33), along with the highest number and length of root hairs. The coconut water treatment (B1) produced values that were statistically comparable to those of Golden Grow for most sprout growth variables. Meanwhile, soaking the seeds in plain water (B0) consistently produced the lowest values for all observed variables.

These findings indicate that soaking seeds in germination stimulants containing auxin, such as Golden Grow and coconut water, can be recommended as a practical pre-planting treatment to improve the viability, vigor, and early growth performance of Arabica coffee seeds prior to propagation. Further research is recommended to determine the optimal concentration and duration of soaking in Golden Grow and coconut water to maximize germination rate and seedling vigor while minimizing potential inhibitory effects caused by excessive auxin concentrations.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to the Master's Program in Dryland Agriculture, Faculty of Agriculture, Udayana University, for the academic guidance, facilities, and continuous support provided throughout the completion of this research.

REFERENCES

- 1) Adibah, F. S. Fadzillah, Darshan, R. R., Mahmod, N. H., Nordin, M. N., Razak, M. H. Abd., Karim, F. N. Abd. dan Nor, W. N. A. N. W. Mohd. 2025. Auxin Priming Promotes Seed Germination and Seedling Growth of Spinach (*Amaranthus tricolor*). *Pertanika Proceedings*, 1(7) : 1-8.
- 2) Alarcon, M. Victoria, Salguero, J. dan Lloret, P. G. 2019. Auxin Modulated Initiation of Lateral Roots Is Linked to Pericycle Cell Length in Maize. *Frontiers in Plant Science*, 10 : 1-10. DOI : 10.3389/fpls.2019.00011.
- 3) Armalia, I., Wahyuningsih, S., Handayani, T. T. dan Mahfut. 2024. The Effects of Gibberellin Concentration and Soaking Time on the Viability of Coffee Seeds (*Coffea canephora* Pierre ex A. Froehner). *AGROSCRIPT Journal of Applied Agricultural Science*, 6(1) : 32-45.

The Effect of Soaking Medium Type on the Viability, Vigor and Early Growth of Arabica Coffee Seeds (*Coffea arabica* L.)

- 4) Bali Provincial Central Statistics Agency. 2025. Bali Province in Figures 2025. Denpasar: BPS-Statistics Indonesia.
- 5) Bali Provincial Department of Agriculture and Food Security. 2024. Statistical Figures on Plantations for 2023. Denpasar: Bali Provincial Department of Agriculture and Food Security.
- 6) Directorate General of Plantations. 2023. Improving Capabilities for Managing Pests and Diseases in Coffee Crops. Ditjenbun.Pertanian.Go.Id. <https://ditjenbun.pertanian.go.id/peningkatan-kapabilitaspenanganan-opt-tanaman-kopi/>
- 7) Gebeyehu, B. (2020). Effect of Seed Storage Period and Storage Environment on Seed Quality. *International Journal of Applied Agricultural Sciences*, 6(6): 185.
- 8) Hidayati, Restu Ike dan Subroto, G. 2018. Growth of Coffee Seedlings (*Coffea* sp.) Produced by Hypocotyl Grafting in Response to Different Types and Concentrations of Plant Growth Regulators. *Agritrop*, 16(1) : 149-163.
- 9) Li, J., Feng, N., Zheng, D., Du, X., Wu, J. dan Wang, X. 2024. Regulation of seed soaking with indole-3-butyric acid potassium salt (IBA-K) on rapeseed (*Brassica napus* L.) seedlings under NaCl stress. *BMC Plant Biology*, 24, 841 : 1-17. DOI : <https://doi.org/10.1186/s12870-024-05586-4>.
- 10) Murni, Ekarista, Rai, I. N. dan Mayadewi, N. N. Ari. 2025. Effect of Seed Soaking with Golden Grow on Growth, Yield dan Yield Quality of Maize (*Zea mays* L.). *International Journal of Multidisciplinary Research and Analysis*, 8 : 3650-3654. DOI: 10.47191/ijmra/v8-i06-72.
- 11) Nurhaliza, A., Priyadi, R., dan Sunarya, Y. 2023. The Effect of Various Methods for Breaking the Dormancy of Arabica Coffee Seeds (*Coffea arabica* L.) on Germination. *Journal of Agrotechnology and Crop Science*, 1(1) : 35-43.
- 12) Putra, A., Tafanto, H., Wijayanto, B., dan Wartapa, A. 2022. The Effect of Coconut Water Concentration and Soaking Time on the Viability of Soybean Seeds (*Glycine max* (L.) Merrill) During the Invigoration Process. *Agrosains : Jurnal Penelitian Agronomi*, 24(2) : 74-83.
- 13) Reed, Jason W., Wu, M. F., Reeves, P. H., Hodgens, C., Yadav, V., Hayes, S. dan Pierik, R. 2018. Three Auxin Response Factors Promote Hypocotyl Elongation. *Plant Physiology*, 178 : 864-875.
- 14) Roychoudhry, Suruchi dan Kepinski, S. 2022. Auxin in Root Development. *Cold Spring Harb Perspect Biol*, 14 : 1-22. DOI : 10.1101/cshperspect.a039933.
- 15) Wang, J., Jin, D., Deng, Z., Zheng, L., Guo, P., Ji, Y., Song, Z., Zeng, H.Y., Kinoshita, T., Liao, Z., Chen, H., Deng, X.W. dan Wei, N. 2025. The Apoplastic pH is a Key Determinant in The Hypocotyl Growth Response to Auxin Dosage dan Light. *Nature Plants*, 11 : 279-294. DOI : <https://doi.org/10.1038/s41477-025-01910-4>.



There is an Open Access article, distributed under the term of the Creative Commons Attribution – Non Commercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>), which permits remixing, adapting and building upon the work for non-commercial use, provided the original work is properly cited.