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Effect of GA_3 Soaking Duration on Germination of Robusta Coffee Seeds

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ABSTRACT

Robusta coffee seeds (*Coffea canephora*) exhibit relatively long physiological dormancy, which often constrains seedling production. One approach to accelerate seed germination is soaking seeds in gibberellic acid (GA_3). This study aimed to evaluate the effect of GA_3 soaking duration at 250 ppm on germination and early seedling growth of robusta coffee seeds. The experiment was arranged in a Completely Randomized Design (CRD) with a single factor, namely GA_3 soaking duration, consisting of five levels: 0, 12, 24, 36, and 48 hours. Observed parameters included time to dormancy breaking, germination percentage, root length, hypocotyl length, percentage of cotyledon opening, and fresh weight of seedlings. Data were analyzed using analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level. The results showed that GA_3 soaking duration significantly affected dormancy-breaking time, germination percentage, root length, hypocotyl length, and seedling fresh weight, but had no significant effect on cotyledon-opening percentage. Soaking seeds in a GA_3 solution (250 ppm) for 24–36 hours produced the best response, as indicated by faster dormancy-breaking, higher germination percentage, and better early seedling growth. Excessive soaking duration tended to reduce treatment effectiveness. Therefore, an appropriate GA_3 soaking duration is recommended to improve robusta coffee seedling establishment.

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INTRODUCTION

Robusta coffee (*Coffea canephora*) is one of the major plantation commodities in Indonesia, playing an important role in the national economy as a source of foreign exchange and rural livelihood development. Successful coffee cultivation is highly dependent on the availability of high-quality seedlings, characterized by high germination capacity, uniform early growth, and strong seedling vigor (Directorate General of Estate Crops, 2022). However, coffee seedling production often faces

constraints at the germination stage due to seed dormancy.

One of the main problems in coffee nurseries is slow and non-uniform seed germination. Coffee seeds are known to exhibit relatively long physiological dormancy, caused by hormonal imbalance, low metabolic enzyme activity, and limited ability of the embryo to utilize stored food reserves (Bewley et al., 2013). This dormancy results in prolonged nursery periods and high variability in seedling growth, thereby reducing production efficiency and increasing operational costs (Copeland & McDonald, 2001).

Seed germination is a complex physiological process involving a sequence of events beginning with water imbibition, followed by respiratory activation, synthesis of hydrolytic enzymes, and embryo cell elongation. This process is strongly regulated by plant hormones, particularly the balance between inhibitory hormones such as abscisic acid (ABA) and growth-promoting hormones such as gibberellins (Finch-Savage & Leubner-Metzger, 2006). In dormant seeds, the dominance of inhibitory hormones suppresses metabolic activation, resulting in delayed or uneven germination. Seed dormancy and germination are tightly regulated by hormonal balance and environmental cues, particularly the interaction between abscisic acid and gibberellins, which determines the timing of germination and early seedling growth (Nonogaki, 2014; Finch-Savage & Footitt, 2017).

Gibberellins, especially gibberellic acid (GA_3), are well known for their role in breaking dormancy and promoting seed germination. GA_3 stimulates the synthesis of hydrolytic enzymes, particularly α-amylase, which hydrolyzes starch into simple sugars to supply energy for embryo growth (Yamaguchi, 2008). In addition, GA_3 enhances cell elongation by loosening cell walls and increasing tissue plasticity, thereby supporting faster and more uniform early seedling growth (Taiz et al., 2015).

Application of GA_3 to seeds is commonly performed through pre-sowing soaking (seed soaking or seed priming). This method has been shown to effectively accelerate germination and improve seed vigor in various horticultural and plantation crops (Ashraf & Foolad, 2005). However, the effectiveness of GA_3 soaking is strongly influenced by soaking duration and the physiological condition of seeds. Insufficient soaking may result in suboptimal hormone uptake, whereas excessive soaking can cause imbibitional stress, membrane damage, or metabolic imbalance (Bradford, 1986; Paparella et al., 2015).

In coffee, several studies have reported that GA_3 application can accelerate germination and enhance early seedling growth. Nevertheless, seed response to GA_3 soaking duration varies among species and even among seed lots, resulting in different optimal soaking durations (Wintgens, 2009; Nasution, 2020). Therefore, more specific studies on GA_3 soaking duration for robusta coffee seeds are required to obtain accurate and applicable technical recommendations.

Compared with other coffee species such as *Coffea arabica*, robusta coffee (*Coffea canephora*) generally exhibits slower and less uniform germination due to stronger physiological dormancy and a harder endosperm structure (Wintgens, 2009; Bewley et al., 2013). The thicker endosperm and higher mechanical resistance in robusta seeds can restrict embryo expansion and delay germination (Taiz et al., 2015). This characteristic poses a major constraint in nursery management, particularly in large-scale robusta coffee plantations where uniform and vigorous seedlings are required. Therefore, improving germination performance in robusta coffee seeds is more critical compared to other coffee species.

Based on these considerations, this study aimed to evaluate the effect of GA_3 soaking duration on dormancy breaking time, germination percentage, and early growth of robusta coffee seedlings. The results are expected to contribute to scientific

knowledge in coffee seed physiology and support the development of more effective and efficient robusta coffee nursery technologies.

MATERIALS AND METHODS

The study was conducted at the nursery facility of the Payakumbuh State Agricultural Polytechnic, Tanjung Pati, Harau District, Lima Puluh Kota Regency. Materials used included robusta coffee seeds, river sand, gibberellic acid (GA_3), bamboo, raffia string, and distilled water. The plant material used in this study consisted of robusta coffee (*Coffea canephora*) seeds collected from a farmer plantation in South Solok Regency, West Sumatra, Indonesia. The seeds were obtained from mature and healthy coffee plants representing local robusta populations commonly cultivated in the region. Before the soaking treatment, the initial seed moisture content was estimated to be approximately 30%, which falls within the typical moisture content range of freshly processed coffee seeds. The experiment was arranged in a Completely Randomized Design (CRD) with five treatments representing GA_3 soaking durations: P_o = no soaking, P_1 = 12 hours, P_2 = 24 hours, P_3 = 36 hours, and P_4 = 48 hours. Each treatment was replicated five times, resulting in 25 experimental plots, with each plot consisting of 30 seeds. A total of 750 seeds were used, of which 375 seeds were selected as observation samples (15 seeds per tray).

Seeds were cleaned of pulp residues, washed with clean water, and air-dried. Subsequently, seeds were soaked in a GA_3 solution at a concentration of 250 ppm according to the designated soaking durations. After soaking, seeds were drained and sown in sterilized sand media placed in germination trays. Seeds were maintained under optimal moisture conditions through regular watering. Observations were conducted from sowing until all parameters were recorded. Data were analyzed using analysis of variance (ANOVA) at the 5% significance level, followed by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The results showed that GA_3 soaking duration significantly affected most germination and early growth parameters of robusta coffee seeds.

Time to Dormancy Breaking and Germination Percentage

Table 1. Time to dormancy breaking and germination percentage of robusta coffee seeds at different GA_3 soaking durations

GA_3 soaking duration	Time to dormancy breaking (days)	Germination percentage (%)
0 hours	19,33 a	88,40 b
12 hours	16,00 bc	95,40 a
24 hours	15,00 c	96,80 a
36 hours	16,67 bc	98,20 a
48 hours	18,00 ab	94,00 a
CV = 7,28%		

Values within the same column followed by different lowercase letters are significantly different according to Duncan's New Multiple Range Test (DMRT) at the 5% significance level.

GA_3 soaking duration significantly affected time to dormancy breaking. Soaking for 24 hours resulted in the shortest dormancy-breaking time (15.00 days), whereas non-soaked seeds exhibited the longest dormancy-breaking time (19.33 days). This acceleration indicates that GA_3 effectively overcomes physiological dormancy by activating metabolic processes suppressed during dormancy. According to Bewley et al. (2013), physiological dormancy is closely associated with low enzyme activity and hormonal imbalance, which can be alleviated through exogenous gibberellin application. GA_3 stimulates hydrolytic enzyme synthesis, particularly α-amylase, facilitating starch degradation into simple sugars that support embryo development and accelerate germination (Taiz et al., 2015). Reduced effectiveness observed at 48 hours suggests that excessive soaking may induce physiological stress or hormonal imbalance, thereby slowing germination.

GA_3 soaking duration also significantly affected germination percentage. Germination increased significantly at 12–36 hours compared with the control, with the highest value obtained at 36 hours (98.20%). This result indicates that GA_3 not only accelerates germination but also improves seed viability. Copeland and McDonald (2001) reported that hormonal seed treatments enhance the percentage of normal seedlings by accelerating and synchronizing physiological processes during germination. However, the slight decline in germination percentage at 48 hours suggests that GA_3 application has an optimal duration beyond which negative effects may occur, such as impaired respiration or accumulation of toxic metabolites.

Root Length, Hypocotyl Length, and Fresh Weight

Table 5. Root length, hypocotyl length, and fresh weight of robusta coffee seedlings at different GA_3 soaking durations

GA_3 soaking duration	Root length (cm)	Hypocotyl length (cm)	Fresh weight (g)
0 hours	6,54 e	9,04 d	0,65 a
12 hours	7,70 d	16,08 c	0,65 a
24 hours	8,06 c	17,58 b	0,68 a
36 hours	10,18 a	19,22 a	0,62 ab
48 hours	9,04 b	18,16 b	0,57 b
	CV = 3,21 %	CV = 3,73%	CV= 8,41%

Values within the same column followed by different lowercase letters are significantly different according to Duncan's New Multiple Range Test (DMRT) at the 5% significance level.

Early growth parameters, particularly root and hypocotyl length, showed the highest response at 36 hours of GA_3 soaking. This response is related to the role of GA_3 in enhancing cell wall plasticity and stimulating cell elongation, thereby supporting early vegetative organ development (Salisbury & Ross, 2016). GA_3 increases the activity of enzymes involved in cell wall loosening, enabling more rapid and efficient cell elongation (Taiz et al., 2015). Longer roots at the early germination stage provide physiological advantages by improving water and nutrient uptake. GA_3 also promotes hypocotyl elongation by increasing cell wall elasticity and internode elongation during early seedling growth (Bewley et al., 2013). However, reduced root and hypocotyl length at 48 hours indicates that excessive soaking duration may disrupt seed physiological balance.

Seedling fresh weight was highest at 24 hours of soaking and tended to decline at 36–48 hours. Increased fresh weight at moderate soaking duration reflects better early biomass accumulation due to optimal mobilization of food reserves. GA_3 enhances the transport of hydrolyzed endosperm reserves to the embryo, supporting new tissue formation (Taiz et al., 2015). Conversely, decreased fresh weight at excessive soaking duration suggests metabolic imbalance or cellular damage caused by over-imbibition, thereby reducing growth efficiency (Hartmann et al., 2018).

Overall, GA_3 soaking for 24–36 hours produced the best response for most germination and early growth parameters of robusta coffee seeds, whereas excessive soaking tended to reduce treatment effectiveness.

CONCLUSIONS

GA_3 soaking duration significantly affected dormancy breaking, germination percentage, and early seedling growth of robusta coffee seeds. Soaking seeds in GA_3 solution at a concentration of 250 ppm for 24–36 hours resulted in the best performance, with the fastest dormancy breaking time of 15 days and the highest germination percentage of 98.20%, along with better root and hypocotyl growth. Therefore, GA_3 soaking for 24–36 hours can be recommended as an effective technique to improve the efficiency and uniformity of robusta coffee seedling production. Further studies are recommended to evaluate the interaction between GA_3 concentration and soaking duration under different nursery conditions.

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