Jurnal Biodjati 11(1): 179–187, May 2026
e-ISSN : 2541-4208
p-ISSN : 2548-1606

JURNAL BIODJATI

http://journal.uinsgd.ac.id/index.php/biodjati

Effect of PGRs and Immersion Time on the Growth of Green Jordan Fig Cuttings (*Ficus carica* L.)

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Received: December 31, 2025
Revise from: February 8, 2026
Accepted: May 13, 2026

DOI: 10.15575/biodjati.v11i1.53999

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Abstract. *The Green Jordan variety of fig (Ficus carica L.) is widely propagated through stem cuttings in Indonesia. Selecting the appropriate plant growth regulator (PGR) and determining the optimal immersion time for cuttings is essential to enhance their growth. This research aimed to study the interaction and determine the most effective combination of PGR and immersion time. The research was conducted from March to August 2023 at the Horticulture Seed Center in Jatinangor, Sumedang Regency, West Java. The research used a completely randomized design with two factors: PGR (control, shallot extract, and NAA). The second factor was immersion time (15 minutes and 30 minutes). The results showed no interaction between PGR and immersion time on cutting growth. Independently, shallot extract PGR increased the number of shoots (47.4%) and leaves (212.5%, or 2 times) compared with water-only immersion, while NAA increased root volume by 22%. A 30-minute immersion time influenced shoot emergence time, shoot number, leaf number, and root volume. Shallot extracts, with a 30-minute immersion time, were the most effective treatment for enhancing the growth of Green Jordan fig cuttings.*

Keywords: *Ficus carica L., immersion time, NAA, PGR, shallot.*

INTRODUCTION

The fig, a member of the Moraceae family, is an important crop with various benefits; its fruit is rich in nutrients. These factors contribute to its popularity and its potential for profitable cultivation. Fig plants are generally propagated using stem cuttings, an efficient method for producing uniform plants. However, stem cutting can be hindered by difficulties in meeting hormonal needs, leading to growth problems. Garba et al. (2019) found that stem cuttings in nurseries often exhibit slow root and shoot formation and abnormal growth due to insufficient levels of phytohormones. Although fig plants naturally produce phytohormones, exogenous Plant Growth Regulators (PGRs) are necessary to prevent hormone deficiencies and stunted growth in cuttings. Shallot extract contains phytohormones such as Indole Acetic Acid (IAA), Naphthalene Acetic Acid (NAA), and Benzyl Amino Purine (BAP) (Yunindanova et al., 2018). PGRs like shallot extract can stimulate root and shoot growth in fig cuttings. Abror and Noviyanti (2019) demonstrated that 2 cc of shallot extract PGR improved bud emergence time, number of shoots, bud length, number of leaves, leaf area, wet weight, and root length in fig cuttings.

Citation
Chaidir, L., Shrea, A., & Qurrohman, B. F. T. (2026). Effect of PGRs and Immersion Time on the Growth of Green Jordan Fig Cuttings (*Ficus carica* L.). *Jurnal Biodjati, 11*(1), 179-187.

Additionally, Naphtalane Acetic Acid (NAA) can also stimulate shoot and root growth. NAA, an auxin, induces cell expansion and root initiation (Narukawa-Nara et al., 2016) and is more stable in light than Indole. Furthermore, NAA is not easily broken down by enzymes or heat (Garba et al., 2019). Novitasari et al. (2015) found that 500 ppm NAA increased sprouting by 30% compared to no auxin. PGRs can be applied through immersion, a simple and effective method. However, immersion time and PGR concentration must be considered. Therefore, research on various PGRs and immersion times is needed for Green Jordan fig cuttings (*Ficus carica* L.). This study aimed to determine the interaction between various PGRs and immersion times.

MATERIALS AND METHODS

This research was conducted from March to August 2023 at the Horticulture Seed Center, Jalan Raya Jatinangor, Pasir Banteng, Hegarmanah, Jatinangor, Sumedang Regency, West Java. The location is at an altitude of 721 meters above sea level with coordinates (-6.9239865, 107.7886657). A two-factor Factorial Completely Randomized Design (CRD) with 6 treatment levels and 5 replicates (30 experimental units) was used.

The first factor was PGR (Z) at three levels: z0 (control), z1 (50% shallot extract), and z2 (0.1% NAA). The second factor was immersion time (W) at two levels: w0 (15 minutes) and w1 (30 minutes). The parameters measured were shoot emergence time, shoot number, shoot length, leaf number, leaf area, leaf chlorophyll content, and root volume.

PGR preparation

Shallot extract PGR was prepared by peeling and cleaning 500 g of shallots, then blending them with 1 L of distilled water. The mixture was filtered through a 100-mesh sieve to obtain a 100% filtrate (stock solution) (Abdullah et al., 2019). A 50% solution was created by diluting 100 ml of this filtrate with 100 ml of distilled water. NAA was prepared by mixing 0.1 g of NAA powder with 1000 mL of distilled water to produce a 0.1% NAA solution.

Planting media preparation:

Soil, burnt husks, and sheep manure were mixed in a 2:1:1 ratio (Hindersah et al., 2021). The soil pH was measured before mixing. The resulting media was placed in 20 × 20 cm polybags.

Cuttings immersion

In this research, the Fig stem was used with stem diameters of 0.5-1 cm. The diameter was used as an indicator because the information on the plant age was limited. Fig cuttings were immersed in the PGR solutions to a depth of 5 cm for 15 or 30 minutes. Treatments were labeled for identification.

Planting cuttings

Cuttings were planted upright in the substrate within the polybags, to a depth of 5 cm. The substrate was gently compacted around the cuttings. The nursery microclimate was maintained to meet temperatures (20-27^{o}C) and humidity (40-45%) requirements (Hasanah et al., 2019).

Maintenance

The cuttings were watered daily, weeds were removed manually, and pests and diseases were controlled preventively using resistant varieties and antracol. Cuttings were fertilized with AB mix solution at EC = 1 (Nafisah et al., 2019).

Data Analysis

The variance analysis was used in this research with software DSAASTAT ver 1.201 as a tool for statistical analysis.

RESULTS AND DISCUSSION

The application of PGRs from shallot extract or synthetic PGRs affects the propagation of Fig. The 5% significance level analysis revealed no interaction between PGR and immersion time regarding bud emergence time. However, each treatment independently affected bud emergence. Post-hoc analysis at the 5% significance level demonstrated that shallot extract PGR (z1) and NAA (z2) significantly differed from the water control (z0). Furthermore, the 30-minute immersion (w1) significantly differed from the 15-minute immersion (w0) (Table 1). In Table 1, smaller average values indicate faster shoot emergence, while larger values indicate slower emergence.

NAA (z2) and shallot extract (z1) accelerated shoot emergence. Growth regulators enhance plant development, which increases a plant's capacity to utilize food reserves for new cell and organ formation (Rifai & Wulandari, 2020). NAA, a synthetic auxin, promotes seedling growth, root elongation, fibrous root formation, and shoot cell elongation. The effectiveness of shallot extract PGR in accelerating budding is consistent with the role of auxin in shallots. Shallot extract contains auxin and thiamin, natural growth regulators that enhance plant growth and development (Rifai & Wulandari, 2020). Auxin influences shoot emergence by stimulating cell division and elongation in tissues, thereby promoting bud formation (Muslimah et al., 2015). The 30-minute immersion likely facilitates greater PGR diffusion into fig stem cells, aiding the cuttings in utilizing carbohydrate reserves for organ development, such as buds (Maisari et al., 2021).

The 5% significance level analysis indicated no interaction between PGR and immersion time regarding the number of shoots. However, PGR and immersion time independently affected shoot number at 2, 4, and 6 WAP. At 8 WAP, no interaction or independent effect was observed. Shallot extract PGR (z1) resulted in the highest number of shoots at 2 WAP (2.70 shoots) and 4 WAP (2.70 shoots), whereas 30-minute immersion (w1) resulted in 2.27 shoots at 2 WAP and 2.80 shoots at 4 WAP. At 6 WAP, shallot extract PGR (z1) produced the highest number of shoots (3.40 shoots) (Table 2).

Table 1. The effect of various PGR and immersion time on bud emergence time

Treatment	Average Bud Emergence Time (WAP)*
Various kinds of PGRs (Z)	
z0 (Water)	11.90 ± 1.19[b]
z1 (Shallot Extract 50%)	7.70 ± 1.06[a]
z2 (NAA 0.1%)	7.30 ± 1.33[a]
Immersion time (W)	
w0 (15 minutes)	9.60 ± 2.26[b]
w1 (30 minutes)	8.33 ± 2.47[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).

*) WAP = Week After Planting

Table 2. The effect of Various PGRs and immersion time on the number of shoots

Treatment	Average Number of Shoots			
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**
Various kinds of PGRs (Z)				
z0 (Water)	1.20 ± 0.42[a]	1.10 ± 0.32[a]	1.50 ± 0.85[a]	1.90 ± 1.10[a]
z1 (Shallot Extract 50%)	2.70 ± 1.34[b]	2.70 ± 1.70[b]	3.40 ± 1.78[b]	2.80 ± 1.75[a]
z2 (NAA 0.1%)	1.80 ± 0.92[a]	2.60 ± 2.27[b]	3.30 ± 1.77[b]	3.50 ± 1.58[a]
Immersion time (W)				
w0 (15 minutes)	1.53 ± 0.74[a]	1.47 ± 0.74[a]	2.53 ± 1.60[a]	2.67 ± 1.68[a]
w1 (30 minutes)	2.27 ± 1.33[b]	2.80 ± 2.21[b]	2.93 ± 1.87[a]	2.80 ± 1.57[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

Shallot extract contains auxin, which promotes shoot growth (Tambunan et al., 2018). Exogenous auxin stimulates shoot growth at the lower part of the cuttings, and the hormone moves acropetally to form buds (Swarup & Bhosale, 2019). The number of buds on cuttings also influences shoot number (Caplan et al., 2018). Buds are important for cutting growth because they contain phytohormones and store carbohydrates and proteins (Lloret et al., 2018). Mayanti and Achmad (2021) suggest that ample food reserves and phytohormones in cuttings promote the development of larger shoots and roots. Shoot length showed no interaction or independent effect of PGR and immersion time on shoot length (Table 3). Shoot length is influenced by auxins and cytokinins.

Žižková et al. (2017) reported that auxin affects cytokinin activity and promotes shoot length by stimulating cell elongation in the stem. High auxin concentrations can hinder differentiation because meristem cell division exceeds differentiation into buds and leaves (cellular growth overlaps). In this study, high auxin levels likely reduced cytokinin activity, resulting in no significant difference in shoot length. Number of leaves. The 5% significance level analysis showed no interaction between PGR and immersion time. However, PGR and immersion time independently affected leaf number at 6 and 8 WAP. At 6 WAP, shallot extract PGR (z1) and NAA (z2) significantly increased leaf number compared to water (z0), but there was no difference between z1 and z2. 30-minute immersion (w1) significantly increased leaf number compared to 15-minute immersion (w0). Similar results were observed at 8 DAP (Table 4).

Table 3. The effect of various PGRs and immersion time on shoot length

Treatment	Average Bud Length (cm)			
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**
Various kinds of PGRs (Z)				
z0 (Water)	0.24 ± 0.06[a]	0.25 ± 0.06[a]	0.53 ± 0.30[a]	0.46 ± 0.29[a]
z1 (Shallot Extract 50%)	0.19 ± 0.14[a]	0.23 ± 0.11[a]	0.44 ± 0.16[a]	0.64 ± 0.41[a]
z2 (NAA 0.1%)	0.24 ± 0.16[a]	0.21 ± 0.14[a]	0.49 ± 0.21[a]	0.47 ± 0.18[a]
Immersion time (W)				
w0 (15 minutes)	0.25 ± 0.13[a]	0.23 ± 0.11[a]	0.47 ± 0.24[a]	0.56 ± 0.34[a]
w1 (30 minutes)	0.19 ± 0.12[a]	0.22 ± 0.10[a]	0.50 ± 0.21[a]	0.49± 0.28[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

Table 4. The effect of various PGRs and immersion time on the number of leaves

Treatment	Average Number of Leaves*		
	4 WAP	6 WAP	8 WAP
Various kinds of PGRs (Z)			
z0 (Water)	0.40 ± 0.70[a]	1.50 ± 0.71[a]	3.20 ± 1.62[a]
z1 (Shallot Extract 50%)	2.70 ± 2.71[a]	5.10 ± 1.45[b]	10.00 ± 2.50[b]
z2 (NAA 0.1%)	2.00 ± 2.11[a]	3.80 ± 1.48[b]	8.20 ± 3.05[b]
Immersion time (W)			
w0 (15 minutes)	1.80 ± 2.40[a]	2.87 ± 1.46[a]	6.40 ± 3.60[a]
w1 (30 minutes)	1.60 ± 2.03[a]	4.07 ± 2.22[b]	7.87 ± 3.91[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

Backes et al. (2018) reported that shallot extract contains essential nutrients for plants, including iron (Fe), potassium (K), phosphorus (P), and magnesium (Mg), as well as auxin and gibberellin, which function as PGRs. Leaf number is closely related to shoot growth; more leaves indicate better shoot development. Leaf number increases with shoot growth because longer shoots have more internodes and nodes where leaves develop (Sarrou et al., 2014). Root growth also influences leaf development by regulating nutrient absorption (Pratiwi et al., 2019).

Leaf Area showed no interaction or independent effect of PGR and immersion time on leaf area (Table 5). Leaf area is influenced by cell division and enlargement (Taiz et al., 2015). Water availability also plays a role; open stomata allow CO2 to enter the leaf for photosynthesis, producing assimilates used for cell division and enlargement.

Table 5. The effect of various PGRs and immersion time on leaf area

Treatment	Average Leaf Area 8 WAP (cm2)
Various kinds of PGRs (Z)	
z0 (Water)	35.64 ± 8.63[a]
z1 (Shallot Extract 50%)	40.70 ± 16.00[a]
z2 (NAA 0.1%)	47.84 ± 21.81[a]
Immersion time (W)	
w0 (15 minutes)	41.71 ± 18.44[a]
w1 (30 minutes)	41.08 ± 15.16[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

The auxin levels in shallot extract PGR and NAA, combined with the immersion times used, may have been insufficient to increase leaf area. Casanova-Sáez et al. (2021) state that auxin regulates hormone production, promoting cell division and shoot formation, which influences leaf number and area. However, leaf area growth is also influenced by cytokinins, which act synergistically with auxin. Wu et al. (2021) indicate that cytokinins promote chlorophyll formation in leaves and stimulate leaf expansion. Immersion time also affects leaf area development.

The immersion time used may have been too short for shallot extract PGR and NAA to adequately diffuse into leaf cells, resulting in no significant difference in leaf area. Karimah et al. (2013) suggest that natural PGRs may not be fully absorbed by plants during growth, potentially masking their effects on the parameters tested. Besides hormones, leaf area growth is influenced by nutrient availability in the growing media, particularly nitrogen. In this study, nitrogen levels were consistent across treatments. Therefore, the treatments did not differ significantly from the control. Soil nitrogen availability depends on the mineralization of organic matter by microorganisms, converting organic N to NH4+ and NO3- (Spataru, 2017).

Chlorophyll Content showed no interaction or independent effect of PGR and immersion time on chlorophyll content (Table 6). Chlorophyll, a pigment in chloroplasts, absorbs light energy during photosynthesis (Tränkner et al., 2018).

Table 6. The effect of various PGRs and immersion time on the number of leaf chlorophyll

Treatment	Average Amount of Leaf Chlorophyll (mg mm^{-2})		
	4 WAP	6 WAP	8 WAP
Various kinds of PGRs (Z)			
z0 (Water)	8.62 ± 18.17[a]	40.12 ± 28.70[a]	41.20 ± 5.72[a]
z1 (Shallot Extract 50%)	32.36 ± 37.25[a]	52.81 ± 10.63[a]	42.22 ± 4.75[a]
z2 (NAA 0.1%)	27.29 ± 28.85[a]	50.08 ± 13.62[a]	42.10 ± 5.32[a]
Immersion time (W)			
w0 (15 minutes)	21.17 ± 27.34[a]	46.75 ± 19.62[a]	41.08 ± 5.93[a]
w1 (30 minutes)	24.34 ± 33.32[a]	48.59 ± 19.37[a]	42.59 ± 4.22[a]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

Nutrients involved in chlorophyll formation include nitrogen (N), iron (Fe), copper (Cu), and magnesium (Mg). Wardani et al. (2022) state that nitrogen is a component of the chlorophyll molecule, controlling the plant's photosynthetic ability. Nitrogen is a constituent of chlorophyll pigments, synthesizing amino acids and proteins, and stimulating green leaf pigment formation. Iron and copper also influence chlorophyll formation; iron is involved in its formation, while copper is a constituent of enzymes, aids in chlorophyll formation, and participates in carbohydrate metabolism. Magnesium (Mg++) is also required for photosynthesis (Tränkner et al., 2018).

Root Volume (Table 7) showed no interaction between PGR and immersion time. However, each treatment had an independent effect. Post-hoc test at the 5% significance level showed that NAA (z2) significantly increased root volume compared to water (z0) and shallot extract PGR (z1), while there was no significant difference between z0 and z1. 30-minute immersion (w1) significantly increased root volume compared to 15-minute immersion (w0). These results align with Fachira et al. (2022), who reported that NAA increases root number and volume.

Table 7. The effect of applying various PGRs and immersion time on root volume

Treatment	Average Root Volume 8 WAP (cm^3)
Various kinds of PGRs (Z)	
z0 (Water)	1.20 ± 1.49[a]
z1 (Shallot Extract 50%)	2.50 ± 1.49[b]
z2 (NAA 0.1%)	3.05 ± 1.49[c]
Immersion time (W)	
w0 (15 minutes)	1.77 ± 1.46[a]
w1 (30 minutes)	2.87 ± 1.46[b]

*) Values with the same letter are not significantly different (DMRT, p = 0.05).
*) WAP = Week After Planting

A 30-minute immersion time yields the best results for root volume. This is because 30 minutes is the optimal immersion duration. Ansar & Abdul (2018) state that PGR immersion effectiveness depends on several factors, including the duration of cuttings' immersion in the solution. Longer immersion increases solution uptake by cells, and immersion time must be adjusted to the solution's concentration.

CONCLUSION

The study concludes that PGR type and immersion time do not interact to affect the growth of Green Jordan fig cuttings. Independently, shallot extract PGR affects the number of shoots and leaves, while NAA affects root volume. A 30-minute immersion time influences bud emergence time, shoot number, leaf number, and root volume. The most effective treatment is shallot extract PGR with a 30-minute immersion.

AUTHOR CONTRIBUTION

L.C. contributed to conceptualization, methodology, formal analysis, and writing of the original draft. **A.S.** contributed to data curation, investigation, and visualization. **B.P.** contributed to supervision, validation, and writing through review and editing.

ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation to all parties involved in completing this research. They extend particular thanks to the Department of Agrotechnology, UIN Sunan Gunung Djati Bandung, for their invaluable facilities and support throughout the research.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this research, including financial, personal, or institutional relationships that could have influenced the study or its findings.

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