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Growth and Peroxidase Activity in Oil Palm Seedlings (*Elaeis guineensis* Jacq.) Against Gibberellin and Watering Intervals in the Main-nursery Phase

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Abstract

Oil palm is an important plantation commodity in Indonesia and has considerable potential for further development, particularly in Riau Province, where it is widely cultivated. In oil palm cultivation, seedlings are expected to exhibit normal growth without any signs of abnormalities. One approach to obtaining healthy, normally growing oil palm seedlings is regular watering, which ensures adequate water availability and distribution and supports cell elongation and plant growth. Improper plant care, particularly inadequate water availability, can disrupt vegetative growth. Under water-deficit conditions, plant metabolic activity may decrease, resulting in physiological stress. This study aimed to analyze the growth responses and peroxidase activity of oil palm seedlings to the application of gibberellin and different watering intervals. The research was conducted in a private garden on Jl. Hangtuah Ujung, Pekanbaru, using a factorial experiment arranged in a Completely Randomized Design (CRD). The experiment consisted of two factors. The first factor was gibberellin concentration, with three levels: 50 mg/L, 100 mg/L, and 150 mg/L. The second factor was the watering interval, comprising three levels: once every 2 days, once every 4 days, and once every 6 days. The two factors were combined to produce nine treatment combinations, with each treatment replicated three times, resulting in 27 experimental units. Each experimental unit consisted of four plants, three of which were used as sample plants. The observed parameters included stem height, stem diameter, crown fresh weight, chlorophyll content, and peroxidase enzyme activity. The results showed that the application of gibberellin at a concentration of 150 mg/L combined with a watering interval of once every 2 days resulted in greater stem height, stem diameter, fresh weight, dry weight, and chlorophyll content than the other treatments. In contrast, the application of gibberellin at 50 mg/L combined with a watering interval of once every 6 days resulted in higher peroxidase enzyme activity.

Keywords: Antioxidants, H₂O₂, Hormones, Reactive Oxygen Species, Water Stress

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a tropical plant native to West Africa and is now widely cultivated in various tropical regions, including Indonesia. In Indonesia, oil palm plantations are predominantly found in Sumatra and Kalimantan, the main centres of national crude palm oil (CPO) production (Aprilia, 2020).

The production of high-quality crops requires superior planting material, making the nursery stage a critical determinant of successful oil palm cultivation. The quality of seedlings is influenced not only by the origin of the

seeds or varieties but also by management practices during the nursery stage, particularly watering and fertilization. At this stage, seedlings are highly sensitive to both water deficiency and excess water. Improper watering can inhibit root growth, cause leaf yellowing, stunt seedling growth, and even kill seedlings.

Watering intervals are one of the major challenges in oil palm nurseries. Oil palm seedlings require an adequate water supply to support photosynthesis, nutrient uptake, and optimal tissue development. Therefore, watering intervals are an important factor affecting seedling growth

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during the nursery stage. Insufficient watering can induce water stress, which may impair seedling growth and metabolic processes and increase the production of reactive oxygen species (ROS). One of the important ROS generated under stress conditions is hydrogen peroxide (H_2O_2). Excessive accumulation of ROS in seedlings can cause cellular damage, thereby inhibiting growth and, under severe conditions, leading to seedling death.

Plants can mitigate ROS-induced damage through the activity of antioxidant enzymes, including peroxidase. Peroxidase plays an important role in ROS detoxification by reducing H_2O_2 to water and other less reactive compounds. The activity of peroxidase may be influenced by the application of growth regulators such as gibberellins and amino acids, including L-glutamic acid. Gibberellin application may stimulate antioxidant defense mechanisms and enhance the activity of antioxidant enzymes involved in ROS detoxification. Thus, gibberellin can reduce oxidative stress and enhance antioxidant activity, particularly peroxidase activity, while also promoting seedling growth.

Gibberellin is a plant growth regulator that plays a role in cell expansion and division, breaking bud dormancy, and promoting stem growth and elongation (Murrinie et al.,

2021). Gibberellin maintains the balance of water potential in plant tissues. It supports the process of transferring photosynthesis products and nutrients to all parts of the plant, so that the detrimental impacts caused by stress can be minimized (Meriem et al., 2023). Administration of 404.2 μM of gibberellin increased the activity of the peroxidase enzyme, thereby reducing the damage caused by abiotic stress (Guo et al., 2022). This research examines the effects of watering intervals and gibberellins on growth and peroxidase activity in coconut palm oil seeds. This research aims to analyse the response of growth and peroxidase activity in coconut palm oil seeds to watering intervals and gibberellins. This research is expected to provide scientific information for managing coconut palm oil through appropriate watering and the application of biostimulants.

2. Material and Methods

This research was conducted on Jln. Hangtuah Ujung, Gang. Handayani, Tenayan Raya District, Pekanbaru City, at coordinates 0.5057377 East Longitude, 101.5022839 North Latitude, altitude 41.3 meters above sea level. This research used a factorial experiment arranged in a completely randomised design (CRD). The factors in this research consist of 2 factors, namely,

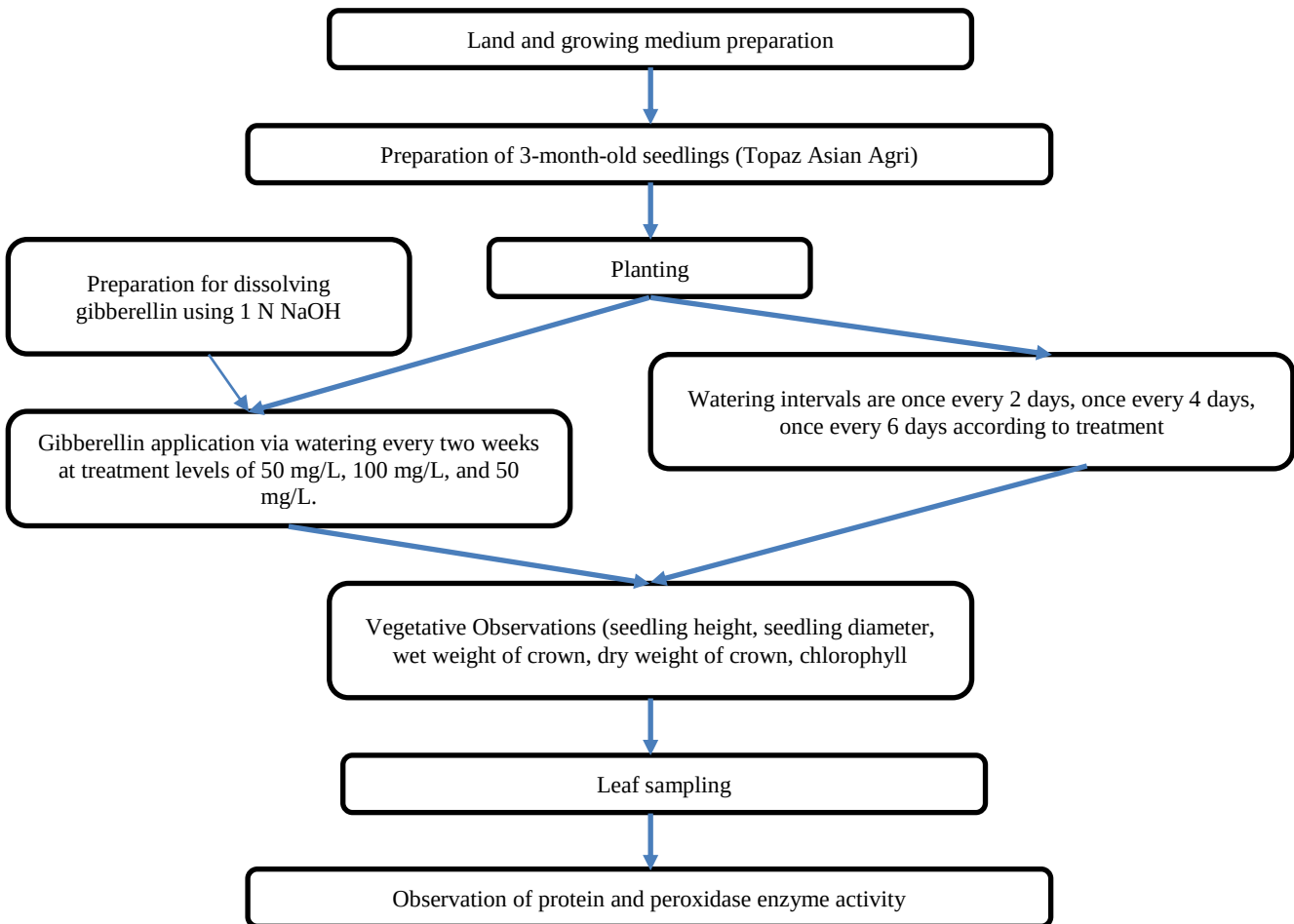


Figure 1. Research Flowchart

Gibberellin concentration consists of 50 mg /L of gibberellin , 100 mg /L of gibberellin and 150 mg /L of gibberellin , the second factor is the watering interval which consists of a watering interval of once every 2 days, a watering interval of once every 4 days and a watering interval of once every 6 days.

The two factors were combined to produce 9 treatment combinations, each repeated 3 times, resulting in 27 experimental units. Each experimental unit consisted of 4 plants, 3 of which served as sample plants.

The final observation data were analyzed statistically using analysis of variance (ANOVA). If the calculated F value is greater than the F table value, then the Honestly Significant Difference (HSD) test is continued at the 5% level. The results of the analysis of variance that had a significant effect were tested using Duncan's 5% test. Data analysis was done using R version 4.5.2.

The materials used in this study were 3-month-old Topaz variety oil palm seedlings, gibberellin and 1 N NaOH solution . The tools used in this study were machetes, hoes, buckets, hoses, sprayers , raffia ropes, scissors, watering cans, polybags , paranets , labels, stationery, meters, vernier calipers, wet and dry thermometers. dry , plastic samples, Styrofoam, spectrophotometer , measuring cup, dropper pipette, Alteco

glue , mica, oven, filter paper, centrifuge , cuvette.

Implementation of research, The preparation of the nursery land is first cleared of weeds. The shade will be made with a height of 2 meters, a length of 5 meters and a width of 12 meters—the transparent plastic roof and surrounded by white paranet. The topsoil planting medium, mixed with 2:1 manure, is put into a 40x35 cm polybag. The planting distance is 40 cm, with a planting hole of 7 cm planting hole. Gibberellin treatment is given every 3 weeks, and L-glutamic acid as a supporting treatment is given every 3 weeks with a concentration of 400 mg / L of water. While the watering interval treatment is carried out with the treatment level, Observations were made at the end of the study: seedling height, number of leaves, stem diameter, wet weight of the crown, dry weight of the crown, stomata, chlorophyll and peroxidase enzyme activity.

3. Results and Discussion

3.1. Seedling Height

Observations of the growth of oil palm seedlings showed that the administration of gibberellin and watering intervals, both singly and in interaction, had a significant effect on increasing the height of oil palm seedlings, as presented in Table 1.

Table 1. Average seedling height in relation to the interaction of gibberellin and watering interval

Gibberellin (mg /L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
50	92.13 ± 1.65de	84.30 ± 0.57ef	78.09 ± 0.64f
100	117.56 ± 1.17b	106.16 ± 2.79c	93.42 ± 0.66d
150	128.33 ± 0.93a	116.85 ± 1.96b	104.04 ± 3.07c

Description: The numbers in the table followed with the same letter show no significant difference in BNJ test at 5% level

150 mg /L gibberellin treatment and a watering interval of every two days resulted in the highest seedling height compared to the other treatments. Increasing the gibberellin concentration to 150 mg /L significantly increased seedling height. Gibberellin stimulates cell division and elongation in the apical meristem tissue of oil palm seedling stems. Consequently, seedling height increased with increasing concentration.

With a watering interval of every two days, seedling height reached 128.33 cm; however, with a four-day interval, the height decreased to 116.83 cm, and with a six-day interval, it dropped to 104.03 cm. Under the two-day watering regimen, the application of 150 mg/L of gibberellin resulted in the greatest seedling height; the gibberellin optimally triggered signalling pathways, and—aided by the watering—cell turgor pressure increased, leading to optimal height growth. This aligns with research by Sari et al. (2026), which found that applying gibberellin at a dosage of 100 mg/L increased the height of eggplant seedlings.

Gibberellin is less effective in increasing seedling

height when watering every 6 days. At a watering interval of once every 6 days, seedling height growth decreased; this is related to water shortages causing seedlings to experience water stress, so that DELLA proteins increase and are strengthened with the help of ABA, so that gibberellin signaling in stimulating stem elongation begins to decline. Providing a watering interval of once every 4 days increased plant height by 57.86 cm, while decreasing the watering interval to once every 6 days, seedlings experienced a decrease in height of 53.11 cm (Castena et al., 2018).

In watering every 2 days, water distribution is sufficient to maintain nutrient absorption and increase cell development, so that cell turgor pressure increases, with the help of gibberellins triggering increased height growth, but with a decrease in the watering interval of 4 days, the seedlings begin to reduce height growth activity, to maintain cell survival, while at a watering interval of 6 days, with less water availability in the soil, and absorption is disrupted, the seedlings inhibit their growth, gibberellins indicate a slow increase in growth. However, increasing

ABA and peroxidase enzyme activity inhibit growth by increasing ROS and disrupting seedling development. Water stress makes seedlings reduce cell expansion and elongation due to increased ABA accumulation, so that cells are unable to grow when there is a lack of water. When water stress occurs, turgor pressure weakens, resulting in turgor being unable to push cells to elongate, resulting in growth slowing down until it stops (Ortega, 2025).

3.2. Seed Diameter

Observations of the growth of the stem diameter of oil palm seedlings showed that the administration of gibberellins alone or the interaction between gibberellins and watering intervals had no significant effect. In contrast, the watering interval alone had a significant effect on increasing the stem diameter of oil palm seedlings, as presented in Table 2.

Table 2. Average seedling diameter in relation to the interaction of gibberellin and watering interval

Gibberellin (ml/L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
		mm.....	
50	33.28 ± 0.52abc	27.68 ± 2.64de	22.87 ± 0.28ef
100	34.87 ± 0.17ab	29.51 ± 1.44bcd	24.22 ± 0.36def
150	37.83 ± 0.88a	29.29 ± 0.59cd	21.72 ± 0.39f

Description : The numbers in the table followed with the same letter show No different real in BNJ test at 5% level

In the treatment of 150 ml/L gibberellin and a watering interval of once every 2 days, the highest increase in stem diameter was 37.83 cm, compared to the treatment of gibberellin and other watering intervals. The increase in stem diameter was dominated by the watering interval of once every 2 days, gibberellin alone was not able to increase the diameter of the seedlings, this is related to gibberellin only being able to stimulate cell division and elongation; gibberellin requires auxin in increasing stem diameter, and also optimal watering. cambium lateral meristem tissue that makes secondary growth, which is silent, holding stem diameter size mastered between gibberellin and auxin. Not just a usual, ARF7 appears as bridge crucial, stringing together signal auxin via IAA9 to gibberellin via RGL1/DELLA so that affect the stem diameter plant (Hu et al., 2022).

Watering every 2 days is the main factor in increasing stem diameter, water can increase cell turgor pressure, so that cells can expand, and hormonal and nutrient distribution can be distributed to all parts of the plant, one of which is increasing stem diameter. While at a watering interval of 6 days physiological functions are disrupted, stem diameter decreases, so that osmotic pressure in the cells is low, water content in the stem is reduced, seedlings protect themselves by reducing diameter and growth, so

water discharge can be limited until the state where water is rooted and absorbed into the stem is available again.

At a watering interval of once every 4 days and the administration of 150 mg / L gibberellin, the seedling diameter decreased by 29.29 cm and at a watering interval of once every 6 days, the seedling diameter decreased again by 21.73 cm. The provision of a watering interval of once every 4 days affected an increase in stem diameter by 5.59 mm, with a decrease in the watering interval of once every 6 days the diameter decreased by 5.28 mm (Castena et al., 2018).

Water stress immediately reduces stem diameter; water reserves decline, radial growth is damaged first, the cambium weakens, and xylem and phloem cease completely. Photosynthesis decreases, and carbon for stem biomass is rapidly depleted. Not only does it stop, but the stem shrinks, and dry tissue loses water. (Zhang et al., 2025).

3.3. Wet Weight of the canopy

Observations of the growth of the wet weight of oil palm crowns showed that the administration of gibberellin and watering intervals, both singly and in interaction, had a significant effect on increasing the wet weight of oil palm crowns, as presented in Table 3.

Table 3. Average wet weight of the canopy in relation to the interaction of gibberellin and watering interval

Gibberellin (mg /L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
		g.....	
50	348.90 ± 6.83b	235.03 ± 2.09d	148.96 ± 1.97
100	362.23 ± 0.42b	262.62 ± 0.18c	173.00 ± 0.96e
150	392.97 ± 0.76a	274.12 ± 0.21c	179.57 ± 7.69e

Description : The numbers in the table followed with the same letter show No different real in BNJ test at 5% level

Gibberellin treatment and a watering interval of every two days resulted in the highest increase in canopy wet weight, compared to the gibberellin treatments and other

watering intervals. The high canopy wet weight in this treatment indicates that the combination of high gibberellin concentration and sufficient water availability supports

optimal vegetative plant growth. As the length of the stem and other photosynthetic tissues expands and multiplies, the overall volume of the canopy increases. This will result in an increase in canopy wet weight due to more living tissue containing water and organic matter.

Gibberellin concentration of 150 mg /L provided a better growth response than 50 mg /L and 100 mg /L. This indicates that seedlings require an optimal concentration. Lower concentrations are thought to be unable to stimulate plant metabolic activity maximally, resulting in lower canopy growth compared to the 150 mg /L treatment. A concentration of 150 mg/ L is considered effective in increasing general vegetative growth (including canopy fresh weight) in ornamental plants (Zulfiqar et al., 2019).

Besides gibberellin concentration, the increase in canopy fresh weight also depends on watering frequency. Watering every 2 days provides sufficient water availability for plants so that physiological processes take place more optimally. Water plays an important role in the process of photosynthesis, nutrient translocation, and the formation of plant tissue formation, thus affecting canopy wet weight. Conversely, the treatment of watering every 6 days causes plants to experience drought stress. The administration of 150 mg / L of gibberellin at a watering interval of once every 2 days produces the highest wet weight, while at a watering interval of once every 4 days the canopy wet

weight decreases by 274.12 g, and decreases again at a watering interval of once every 6 days by 179.57 g. The decrease in canopy wet weight is related to the decrease in the watering interval, indicating that longer or less frequent intervals increase seedling stress in line with research (Ghasemnezhad et al., 2025). Reported that giving a watering interval of once every 2 days increases the plant wet weight by 168 g, while decreasing the watering interval to once every 5 days decreases the plant wet weight by 107 g.

Water shortages disrupt plant physiological activity, particularly photosynthesis and nutrient uptake. Plants experiencing a water deficit will close their stomata to reduce water loss through transpiration. Stomatal closure reduces carbon dioxide absorption, thus decreasing the rate of photosynthesis. The longer the interval between waterings, the more stunted growth becomes. (Wahyuni & Anshar, 2024) .

3.4. Dry Weight of the Canopy

Observations of the growth of dry weight of oil palm crowns showed that the administration of gibberellin and watering intervals, both singly and in interaction, had a significant effect on increasing the dry weight of oil palm crowns, as presented in Table 4.

Table 4. Average dry weight of the canopy in relation to the interaction of gibberellin and watering interval

Gibberellin (mg /L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
50	161.92 ± 1.85b	115.99 ± 4.27c	49.23 ± 0.02d
100	162.17 ± 0.70b	116.33 ± 1.20c	56.94 ± 0.43d
150	211.39 ± 0.65a	124.04 ± 2.23c	52.11 ± 0.53d

Description: The numbers in the table followed with the same letter show No different real in the BNJ test at the 5% level.

Gibberellin treatment and a watering interval of once every two days resulted in the highest increase in dry weight of the shoots, compared to other gibberellin treatments and watering intervals. This increase in dry weight of the shoots indicates that the interaction between gibberellin administration and water availability is a key factor in maximizing the accumulation of dry biomass of plants. Gibberellin plays a role in stimulating cell division and elongation, as well as increasing cellular metabolic activity, including photosynthesis and the synthesis of proteins, carbohydrates, and structural components of cells. Physiologically, the increase in dry weight of the shoots at a dose of 150 ppm occurs because GA 3 can improve morphological growth, biochemical activity of plants and increase the length of shoots and roots, shoot biomass, chlorophyll content, total soluble sugars, soluble proteins, as well as phenolic and flavonoid compounds. The increase in chlorophyll is directly related to increased photosynthetic capacity, so that plants can produce more photosynthates, which are then stored as dry matter in the

shoot tissue. (Hasan & Ismail, 2018) .

In addition, gibberellin treatments of 50 mg /L and 100 mg /L showed a lower response because lower hormone concentrations resulted in less optimal stimulation of cell division and elongation, thus limiting dry biomass synthesis. At low doses, the canopy area and the plant's ability to photosynthesise were not optimal, so that the photosynthate produced and accumulated as dry matter was less (Hasan & Ismail, 2018).

The effectiveness of gibberellins depends heavily on the plant's physiological conditions, particularly water availability. Watering every two days maintains optimal cell turgor pressure, supports water and nutrient transport throughout the canopy, and prevents metabolic inhibition from temporary drought. This condition allows gibberellin to work more effectively in increase cell division, tissue expansion, and dry matter accumulation, resulting in a significant increase in canopy biomass. Less frequent watering intervals, such as every four to six days, result in reduced water availability in the growing medium, resulting

in decreased cell turgor pressure and disrupted plant metabolism, resulting in reduced dry biomass accumulation, even though the gibberellin concentration is high. Watering every two days is better because it can maintain stable water availability in the growing medium. In contrast, watering every 4 or 6 days makes plants more susceptible to water deficits. Water deficiency causes stomata to close, reduces CO₂ absorption, decreases photosynthesis, reduces carbohydrate formation, and reduces dry weight.

(Ali et al., 2024).

3.5. Chlorophyll

Observations of the growth of the wet weight of oil palm crowns showed that the administration of gibberellin and watering intervals, both singly and in interaction, had a significant effect on increasing the wet weight of oil palm crowns, as presented in Table 5.

Table 5. Average chlorophyll content in relation to the interaction of gibberellin and watering interval

Gibberellin (mg /L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
	SPAD/u.....		
50	37.33 ± 0.33b	30.90 ± 0.76d	22.00 ± 0.35e
100	39.83 ± 0.44a	32.17 ± 0.09d	21.43 ± 0.19e
150	41.37 ± 0.09a	34.63 ± 0.07c	20.93 ± 0.07e

Description: The numbers in the table followed with the same letter show no significant difference in the BNJ test at 5% level

Gibberellin treatment and a watering interval of once every 2 days resulted in the highest increase in chlorophyll, not significantly different from the 150 mg /L gibberellin treatment and watering every 2 days and significantly different compared to the gibberellin treatment and other watering intervals. This shows that the increase in chlorophyll content is influenced not only by gibberellin concentration of gibberellin, but also by sufficient water availability of sufficient water during plant growth. Administration of gibberellin Increases plant metabolic activity and improves plant growth and development, resulting in active leaf tissue rich in chlorophyll. Optimally developed leaves have more chloroplasts, increasing chlorophyll synthesis. High doses can affect chlorophyll formation and increase plant photosynthetic pigments. (Kusumodewi et al., 2017).

A watering interval of every 2 days also plays a crucial role in maintaining plant chlorophyll content. Adequate water availability helps maintain cell turgor pressure, facilitates nutrient absorption, and supports physiological processes such as photosynthesis and chlorophyll pigment

formation. Conversely, at watering intervals of every 4 days and every 6 days, chlorophyll content tends to be lower even though plants are given gibberellins of 100 mg /L and 150 mg /L, respectively. Under water stress conditions, plants can also experience chlorophyll degradation or damage to photosynthetic pigments, resulting in less green leaf colour and decreased chlorophyll content. Providing a watering interval of every 3 days increased total leaf chlorophyll by 23.60 CCI, and when the interval decreased to every 9 days, the total chlorophyll was 21.17 CCI (Castena et al., 2018). Regular watering intervals produced the highest total chlorophyll ratio compared to longer intervals, and sufficient water helps maintain efficient photosynthesis, thereby increasing chlorophyll production. (Rusmayadi et al., 2025).

3.6. Peroxidase activity

Observations of peroxidase enzyme activity showed that single application and the interaction of gibberellin and watering interval significantly increased peroxidase enzyme activity in oil palm, as shown in Table 6.

Table 6. Average activity of peroxidase enzyme in response to the interaction of gibberellin and watering interval

Gibberellin (mg /L)	Watering Interval		
	Once every 2 days	Once every 4 days	Once every 6 days
	u/ mg /min.....		
50	0.21 ± 0.01d	0.36 ± 0.01c	0.94 ± 0.02a
100	0.22 ± 0.01d	0.39 ± 0.01c	0.97 ± 0.02a
150	0.22 ± 0.01d	0.26 ± 0.01d	0.69 ± 0.02b

Description: The numbers in the table followed with the same letter show no significant difference in the BNJ test at the 5% level.

The treatment of 50 mg /L gibberellin and a watering interval of once every 6 days resulted in the highest peroxidase enzyme activity, not significantly different in the 100 mg /L gibberellin treatment and a 6-day watering interval, and significantly different in other treatments. Gibberellin 50 mg /L increases the activity of the peroxidase enzyme; gibberellin produces signalling that activates antioxidants to reduce radicals, one of which is

ROS.

Peroxidase plays a role in the catalysis of H₂ O₂, thus helping to suppress damage caused by ROS. At a watering interval of once every 6 days, ROS is formed in quite high levels, resulting in a decrease in the physiological function of the seedlings and decreased growth. Gibberellin helps reduce ROS, ROS formation is reduced and inhibited, if ROS is formed in the tissue at

high, plants experience tissue damage and die, ROS accumulate H_2O_2 to form $OH\cdot$ while peroxidase inhibits and reduces H_2O_2 production by decomposing it into O_2 . Gibberellin increases peroxidase activity in corn leaves under stress and helps reduce H_2O_2 content and oxidative damage (K. Sun et al., 2020). While at high concentrations, gibberellin reduces peroxidase (Xue et al., 2018).

In the treatment 6 days of watering very with giving gibberellin 100 mg/L water increases activities enzyme peroxidase as big as $0.97 \pm 0.02a$ u/mg/min while when watering once every 4 days, it decreased to $0.39 \pm 0.01c$, and decreased again when watering once every 2 days to $0.22 \pm 0.01d$



Figure 2. Seedling growth with watering every 2 days (A), every 4 days (B), and every 6 days (C)

The increase in peroxidase enzyme activity was associated with increasing drought stress in the plants.

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