Response of Oil Palm Plant Growth (*Elaeis guineensis* Jacq.) to Aluminium Stress

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Abstract. This research aims to study the response of palm oil plants to Aluminium stress their deficiencies. This experiment used Aluminium (Al) with different concentrations of 0 ppm (Al₀), 100 ppm (Al₁) and 200 ppm (Al₂) dissolved in hoagland liquid media with different old of oil palm plants. Based on the results obtained, the effect of aluminum stress on the wet weight of the plant has a real effect while it has the same effect on plant height and plant root length. Some deficiencies experienced by palm oil plants that are in stress of Al, the first symptom that is seen is the plant roots become shorter and thicker, as a result the growth and development of roots is inhibited and in the long term can cause the ability of plants to absorb nutrients is reduced. Anatomically observations of chlorophyll content and stomata density, where plants aged 6 months have the highest total chlorophyll content (0.059602, 0.05612, and 0.066077) while the lowest chlorophyll content in plants is 2 months old (0.018388, 0.02428 and 0.017978). The density of stomata at 2 months age has the highest values while the lowest density values for plants in 6 months for each treatment.

1. Introduction

Palm oil (*Elaeis guineensis* Jacq.) is the most productive vegetable oil producing plant in the world when compared to other types of vegetable oil producing plants such as canola, coconut, soybean and sunflower. Palm oil is the main crop of plantations in Indonesia, is a plantation plant which occupies an important position in the agricultural sector in general and the plantation sector in particular. This can be seen from the increase in plantation area, oil production and commodity export volume from year to year. Indonesia's palm oil production centers mainly from 6 (six) provinces which contributed 73.69% of the total Indonesian palm oil production. The provinces of Riau and North Sumatra are the largest CPO production centers in Indonesia with contributions of 23.75% and 16.24%, respectively. [1] Palm oil is an annual plant that can reproduce economically until the age of 25-30 years, to support this potential maintenance of vegetative growth is important. Potential land for oil palm cultivation is limited by environmental factors, physical and chemical properties of the soil. Soil fertility is a condition of the ability of the soil to provide adequate and balanced amounts of nutrients so that it supports plant growth and production according to its potential [2]. More than 55 million hectares of agricultural land in Indonesia is acidic. Aluminum (Al) is known as a major factor causing toxicity for plants that grow in acidic soils. Vulnerability of plants to Al stress will cause plants to be susceptible to drought and disruption of nutrient uptake, so that in the long run it will affect their growth and development. Aluminum is one of the supporting nutrients that can cause soil poisoning around plant
roots, so that it can inhibit plant growth and development [3]. According to [4] Al causes disruption of cell division in the root cap and lateral roots and causes an increase in cell rigidity through the formation of pectin cross bonds in the cell wall, reducing DNA replication through increased double chain rigidity.

Aluminum is a rhizotoxic ion that inhibits plant growth and productivity in acidic mineral soils. Although Al inhibits the process of metabolism and plant growth, but to some extent the influence of Al can be tolerated by tolerant plants [5]. The initial symptom that appears in plants that are Al poisoning is a root system that is not well developed [6]. Several studies on the effect of Al on plant root systems have been widely reported, but the mechanism of growth inhibition induced by Al is not widely understood. Plasma membrane of cells at the root tip is the main target of Al toxicity [7]. The main influence of Al on root membrane permeability can be seen only within minutes or hours after Al exposure.

2. Research Methods

2.1 Time and Place of Research
This research was conducted in June 2020 at the Laboratory of Physiology and Plant Tissue Culture, Department of Biology, Faculty of Mathematics and Natural Sciences, University of North Sumatra.

2.2 Plant Preparation and Growing Media
The plants used are palm oil (Elaeis guineensis Jacq.) with varieties of D X P Langkat which are 2 months, 4 months and 6 months old. Plants come from sprouts planted on sand and soil media in the pre nursery stage. Plants are then transferred from the soil growing media to the hoagland liquid media that was previously cleaned from dirt attached to running water. Aeration is done every day in 2 weeks. The form of Al salt used as a treatment is Al-nitrate salt. The seeds were monitored for growth for 2 weeks looking at plant deficiencies and responses.

2.3 Treatment
The treatments in this experiment used Aluminum (Al) with different concentrations of 0 ppm (Al0), 100 ppm (Al1) and 200 ppm (Al2) dissolved in hoagland liquid media with 5 replications per treatment for one type of plant life of 2 months (U1), 4 months (U2) and 6 months (U3).

| Umur Tanaman | Ulangan | Konsentrasi Aluminium (Al) |
|--------------|---------|---------------------------|
|              |         | Al0 | Al1 | Al2 |
| 2 bulan      | 1       | Al0U1 | Al1U1 | Al2U1 |
|              | 2       | Al0U2 | Al1U2 | Al2U2 |
|              | 3       | Al0U3 | Al1U3 | Al2U3 |
| 4 bulan      | 1       | Al0U4 | Al1U4 | Al2U4 |
|              | 2       | Al0U5 | Al1U5 | Al2U5 |
|              | 3       | Al0U6 | Al1U6 | Al2U6 |
| 6 bulan      | 1       | Al0U7 | Al1U7 | Al2U7 |
|              | 2       | Al0U8 | Al1U8 | Al2U8 |
|              | 3       | Al0U9 | Al1U9 | Al2U9 |

Table 1. Design of Aluminum (Al) Concentration Treatment Treatments Plant age (U)
2.4 Observation Parameters
The parameters in this experiment include measurements of plant height, root length, final wet weight and observation of stomata and chlorophyll, as well as plant morphology after treatment.

2.5 Analysis of stomata density and leaf chlorophyll
The stomata density of each leaf sample was calculated based on the method of [8] i.e. by applying a nail polish solution on the underside of the leaf. The dried nail polish is removed with the aid of masking tape and then glued to a glass preparation which has been dripped with iodine solution as a coloring agent. The number of stomata was calculated using a microscope at 400x magnification.

Chlorophyll content was measured using spectrophotometric methods. The leaves used are crushed using a mortar, weighed 0.05 grams. Samples were extracted with 5 ml of 70% acetone stirred until chlorophyll dissolved. Chlorophyll extract was filtered using filter paper. The filtrate obtained was added to the cuvette to further measure the chlorophyll content. The instrument used is a spectrophotometer at wavelengths of 645 nm and 663 nm, after absorbing values, chlorophyll a, chlorophyll b and total chlorophyll are calculated.

3. Results and Discussion

3.1 Wet Plant Weight Parameters
The results of analysis of variance for the parameters of wet weight, plant height and root length showed different results for each parameter observed. Aluminum stress and age significantly affect the wet weight of oil palm plants. This can be seen from the response of oil palm plants which are in stress conditions Al1 and Al2 which have lower wet weight (5.7460 and 5.7193) compared to plants that are in conditions without Al stress which is 7.0320.

Wet weight is a parameter that shows the accumulation of photosynthate and water in the body of the plant. Wet weight is calculated by weighing the plant part immediately after it is removed from the growing media. This is because water is so mobile that it can move from one part to another or is lost through transpiration produced by plants [9].

![Figure 1. Wet Weight Of Oil Palm](image)

From the graph above, there can be a decrease in plant wet weight in aluminum stress, this is caused by damage to the plant root system that is in Al so that the ability of plants to absorb water is reduced. Plant fresh weight can indicate plant metabolic activity and plant fresh weight value is influenced by tissue water content, nutrients and metabolic yield. Decreasing the size and number of cells will also ultimately reduce the weight of plants [10].
3.2 Plant Height Parameters

Plant height is a plant growth variable that is easily observed as a parameter to determine the effect of the environment or the effect of treatment on plants. Based on observations from each treatment the same effect on plant height at all ages. However, there was a decrease in plant height in Al2 treatment when compared to plants in Al0 and Al1 which were not much different. This shows the intolerance of plants to Al concentrations of more than 100 ppm.

Plant height is the result of cell division and elongation. Plant growth is the result of various physiological processes that involve genotypic factors that interact with environmental factors. Growth occurs in terms of increasing size, shape and amount. Growth on plant stems is due to the activity of the apical meristem located at the tip of the shoots. Meristems are composed of initial cells that play the role of forming new cells and derivative cells that will be specialized into certain tissues [2].

![Figure 2. Height Of Oil Palm Plants](image)

3.3 Plant Root Length Parameters

The influence of aluminum stress and age have the same effect on the root length of the plant, but when viewed from the average root length there is still a decrease in root length that does not differ greatly from each other between each treatment. This can be seen in Figure 3.

Plants that are sensitive to Al experience inhibition of plant growth and development, due to stunted root growth. The first symptom that appears from Al poisoning is the root system that does not develop (short and thick) due to inhibition of cell extension [11].

![Figure 3. Length of Oil Palm Roots](image)
Inhibition of plant growth due to Al stress due to the formation of bonds between Al with the root plasma membrane and on the root cell wall and can replace the Ca position in the middle lamella all of which cause inhibition of cell division and root function. Inhibition of root formation in plants that have stressed Al causes a decrease in root length and cell viability because 99% of Al that accumulates in cells is found in cell walls and membranes, related to compounds such as phospholipids found in cell membranes that interfere with membrane permeability and interfere with absorption nutrients regulated by a proton pump. Damage to the roots results in inhibition of absorption of nutrients and water in the soil. Imperfect root growth causes the root system to become shallower and more sensitive to drought. High enough aluminum concentrations in the planting medium can inhibit the growth of some species, not only because their effects damage the availability of phosphate, it also seems to inhibit iron absorption and because of their direct toxic effects on plant metabolism. Al poisoning inhibits the extension and growth of primary roots, as well as blocking the formation of lateral roots and root hairs [12]

3.4 Response of Physiology Variables

3.4.1 Chlorophyll content
From the results obtained in this experiment it can be seen that oil palm plants aged 6 months for each treatment (Control, Al 100 ppm and Al 200 ppm) have the highest total chlorophyll content (0.059602, 0.05612, and 0.066077 ) while the lowest chlorophyll content in plants aged 2 months for each treatment is (0.018388, 0.022428 and 0.017978) so it can be concluded that plant age affects the chlorophyll content of the plant.

With the presence of Al stress in the planting medium the ability of the root to absorb Ca2 is replaced by competitor Al so that root growth is inhibited and this has implications for low Mg2 + uptake and inhibits the formation of chlorophyll [2] The decrease in chlorophyll content that occurs due to damage to roots causes inhibition of absorption of nutrients and water in the soil. Imperfect root growth causes the root system to become shallower and more sensitive to drought. so that if a plant suffers from water shortages due to damage to the root system it will inhibit chlorophyll synthesis in leaves, due to decreased photosynthesis rate and an increase in temperature and respiratory can cause chlorophyll disintegration [13].

3.4.2 Stomata Density
Observation of stomata density in oil palm plants showed that the age of 2 months for each treatment had the highest value (649.90, 524.11, and 507.34) while the lowest density value for 6 months for each treatment (557.65, 511, 53 and 473.79). Stomata are the most important part in the exchange of gases (O2 and CO2) in plants, which is one of the epidermal modifications that are in the abaxial leaves. Stomata density in oil palm plants can be categorized as high density (> 500 / mm2) only in plants aged 6 months with stress Al 200 ppm categorized as medium density (300-500 / mm2).

Stomata develop gradually during organ growth, so that younger organs have fewer stomata than adult organs. Stomata density is closely related to the metabolic or physiological processes of plants (Khoiroh.2014). From the category of stomata density which tends to be high in oil palm plants with stress Al shows a physiological response related to the inhibition of water absorption by roots, where plants that grow in areas that lack water will have a greater stomata density compared to plants that live in the area wet and protected. Plants that have a large stomata density will have a higher transpiration rate than plants with a low stomata density [14].

4. Conclusions
Aluminum stress on oil palm (Elaeis guineensis Jacq.) Aged 2 months, 4 months and 6 months within 10 HST in Hoagland media significantly affected the wet weight of plants and had the same effect on root height and length. There is a decrease from observations of plant height, root length and wet weight of plants due to plant response to Al. Al deficiency can be seen from the morphological
changes in plant roots which become shorter, thicker and stiffer. Physiologically the roots experience growth and development that is inhibited resulting in the absorption of nutrients for plants is also reduced. In addition, due to Al poisoning by plants, plants are also vulnerable to drought stress. Experiments need to be carried out for oil palm plants with older plant age and the determination of the appropriate liquid media in determining the effect of Al stress on plants.

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