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RESEARCH ARTICLE

Growth and initiation of third stage of immature oil palm (*Elaeis guineensis* Jacq.) by giving oil palm frond compost and paclobutrazol

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Abstract

The third stage of immature oil palm is the phase where the plants enter preparation for flowering, so efforts are needed to initiate flowering, one of which is by using plant growth regulators (PGR) such as paclobutrazol. It is expected that the use of oil palm fronds as compost and application to oil palm plants can support sustainable oil palm management activities. Paclobutrazol, as a growth regulator, plays a role in stimulating the flowering of immature oil palm plants. This research aims to determine the response to the growth and development of immature oil palm plants in the third stage by administering palm frond compost and paclobutrazol at certain doses and concentrations. The experiment was carried out from June to December 2020 at the Ciparanje Experimental Garden, Faculty of Agriculture, Universitas Padjadjaran. The experimental design used was a Randomized Block Design (RBD) with 12 treatments and three replications. The experimental results showed that the application of compost to oil palm fronds and paclobutrazol had a significant effect on plant height and stem girth, but there were no significant differences in the number of fronds, leaf area, chlorophyll index, and flowers. All treatments did not produce flower shoots but showed inhibition of vegetative growth in immature oil palm plants in the third stage. The application of 12.8 kg of oil palm frond compost and 150 ppm paclobutrazol had the best effect on the height and girth of the oil palm stem and had an effect that was not significantly different from other treatments on the parameters of a number of fronds, leaf area, leaf chlorophyll, and flower growth.

Keywords

Oil palm frond compost; paclobutrazol; the third stage of immature oil palm

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is one of the commodities that are very important for Indonesia's economic life because it is a vegetable oil-producing commodity in various industries (1). Palm oil is also a contributor to the country's largest foreign exchange and a provider of employment opportunities for various community sectors. Palm oil is a vegetable oil producer with productivity higher than other commodities, so it has great potential for development. The need for palm oil also tends to increase, as evidenced by the increase in the area of cultivated land.

Increasing the productivity of oil palm plants is still a main goal in oil palm plantations in Indonesia. Increasing productivity is performed starting from the seedling period, immature plants, and during the mature plants. Oil palm maintenance during the immature stage period greatly determines the next oil palm productivity. During the immature stages, one of the maintenance activities is fertilization to meet the plant's nutritional needs so that it can grow and develop well. Fertilization consists of both inorganic and organic fertilizers, which are needed by plants. Adding organic material to plants can increase the nutrient content in the soil so that it can be used to help plant growth and development (2).

The growth and development of oil palms are supported by fertilization, which aims to meet the nutritional needs of the plants. The need for large amounts of fertilizers in companies causes the budget of plantation companies to increase so that efforts are required to find other sources of nutrients to reduce the cost of chemical fertilization (3). Oil palm fronds, as waste commonly found in oil palm plantations, can produce 20-30 fronds per year, and only 18-22 fronds can produce fruit. The fronds cut each harvest are 1-3 fronds with a wet weight of about 5.40 kg/frond (4). Fertilization is important in all phases of oil palm, nursery, maintenance of immature plants, and maintenance of mature plants. Application of 1600 g of oil palm frond compost/seedling and 20 g of NPP fertilizer/seedling produces the best dry weight of oil palm seedlings (5). Research by (6) explained that the application of 3.2 kg of oil palm frond compost/ plant and 30 mL of humic acid to immature oil palms had a better effect on height increase and leaf chlorophyll content at 4 months after treatment (MAT) compared to 1.6 kg treatment/plants. Oil palm frond compost can even be used as a substitute for inorganic fertilizer because its application does not show a real difference to the application of inorganic fertilizer according to recommendations.

Before entering the harvesting stage, the oil palm will release a sheath or palm flower bud that grows between the fronds and stem. This indicates that oil palm begins to enter the generative phase, and the vegetative growth begins to be inhibited. Under suitable field conditions, oil palms will flower in the third stage of immature oil palm, but if planted at an altitude of +700 m above sea level, it will be difficult for oil palms to flower. The optimal conditions for oil palm in the highlands and lowlands are different because they concern the suitability of the environment for oil palm growth and development. According to (7), oil palm plants begin to produce flowers after 14 months in the field, but it depends on its growth. The process of initiation of flowering can be accelerated by using a Plant Growth Regulator (PGR) that can inhibit vegetative growth and stimulate generative growth (8), which is paclobutrazol. The use of paclobutrazol causes a decrease in the content of gibberellins so that plants can induce flowers (9).

Flowering initiation can run optimally if the plant's nutrient needs are also fulfilled. The application of oil palm frond compost is expected to be able to meet the needs of plant nutrients, and the use of paclobutrazol can initiate flowering so that both are expected to have a positive influence on the growth and development of the third stages of immature oil palm. Research by (10) showed that the application of 100 ppm paclobutrazol with an application frequency of once a week for six weeks was able to significantly inhibit height growth and increase chlorophyll levels and photosynthesis rate in oil palm seedlings. According to (11), the higher the concentration of paclobutrazol given, the more it will inhibit height growth, thereby accelerating the initiation of flowering.

Based on this explanation, it is necessary to research the combination of treatment of oil palm frond compost and paclobutrazol on the growth and initiation of flowering of the third stage of oil palm plants. It is expected that this combination of treatments can complement each other in meeting the nutrient needs of oil palm plants by providing oil palm frond compost along with faster plant growth entering the generative period by providing the hormone paclobutrazol.

Materials and Methods

Place and time

This research was carried out from June to December 2020 in Ciparanje experimental field, Jatinangor, Faculty of Agriculture, Padjadjaran University, Sumedang at coordinates 107046'22,29'E, 6054'51.55"S at an altitude of ± 752 m above sea level (MASL) with the inceptisol soil (12) and the C type (slightly wet) of rainfall according to the classification of (13).

Experimental design

This experimental design used a Randomized Block Design (RBD). There were 12 treatments and three times replications. Each experimental unit consisted of one plant, so there were 36 experimental units in total. This research used 3-year-old oil palm plants as experimental material. There were 12 treatments and three times repetition. Each experimental unit consisted of one plant, a total of 36 experimental units. The treatment given was palm frond compost and paclobutrazol, whereas the control treatment used 500 g of nitrogen, phosphorus, and potassium (NPP) fertilizer with one application per plant given at the beginning of the treatment. The 12 treatments mentioned were: A = 0.5 kg NPP fertilizer, B = 0.5 kg NPP fertilizer + 50 ppm paclobutrazol, C = 0.5 kg NPP fertilizer + 100 ppm paclobutrazol, D = 0.5 kg NPP fertilizer + 150 ppm paclobutrazol, E = 6.4 kg of palm frond compost, F = 6.4 kg of palm frond compost + 50 ppm paclobutrazol, G = 6.4 kg of palm frond compost + 100 ppm paclobutrazol, H = 6.4 kg of palm frond compost + 150 ppm paclobutrazol, I = 12.8 kg of palm frond compost, J = 12.8 kg composted oil palm frond + 50 ppm paclobutrazol, K = 12.8 kg composted oil palm frond + 100 ppm paclobutrazol and L = 12.8 kg composted oil palm frond + 150 ppm paclobutrazol.

Oil palm compost is made by chopping palm fronds into small pieces to make it easier to decompose when composting processes take place. The EM4 was diluted with water in a ratio of 1:100. Five tablespoons of sugar were added as a source of carbohydrates for microorganisms. The EM4 was given to the fronds to accelerate decomposition and covered with plastic for 2 months.

Palm frond compost is used when it is odorless, which indicates that the decomposition process is complete. Compost of oil palm frond contains C-organic 10, 20%, total N 1.46%, P_2O_5 1.57%, K_2O 0.32%, and C/N 7. The planting material used is the third stage of the immature oil palm variety Simalungun. Soil analysis before treatment was 0.17% total N, 12.14 ppm P_2O_5 P, K-dd 0.93 cmol.kg^{-1}.

The analysis of variance used was the F test (p≤0.05) and used Scott Knott test if it was significantly different. The Scott Knott test was performed by using SASM Agri version 8.2 software.

Observed parameters

The main observations made were the increase in height, stem circumference, number of leaf fronds, leaf area, chlorophyll content, and oil palm flowers. Plant height was measured using a measuring tape from the base to the tallest leaf. Measurements are carried out every two months from 0 month after treatment (MAT) to 6 MAT. Increase in height is calculated by subtracting the nth month measurement results from observations at 0 MAT. The stem circumference was measured using a measuring tape at 10 cm from the soil and measured with millimeter (mm) accuracy. Measurements are carried out every two months from 0 MAT to 6 MAT.

The number of leaf fronds is defined as the number of leaves that have opened completely. The number of leaf fronds were observed every two months and calculated by subtracting its current (observed) amount from the initial observation at 0 MAT. Measurements are carried out every two months from 0 MAT to 6 MAT. The leaf area measured was the area of several sample leaves of the widest leaves on the plant. Measurements are carried out every two months from 0 MAT and 6 MAT. Leaf area was measured using the formula:

$$L = k \times l \times p \quad \text{(Eqn. 1)}$$

Where, L = leaf area (cm^2); k = correction factor (0.55); l = sample average leaf width; p = sample average leaf length (9).

Leaf chlorophyll content was measured using a tool (Apogee Instruments Inc.) with a sensor diameter of 24 mm. It was measured in the 3rd and 4th leaf samples per plant because of the more strategic location for getting sunlight. At the beginning of the research, oil palm plants did not yet have flower sheaths, so paclobutrazol was given to initiate flowering. Flowers estimated to appear from the sheaths that grow in the axils of oil palm leaves. The number of flowers is determined by counting the sheaths that emerge between the front and the palm stem.

Results and Discussion

Plant height

The results showed that treatment with paclobutrazol was able to inhibit the growth of the third stage of immature oil palm plants (Table 1 & 2). The 150 ppm paclobutrazol treatment resulted in a lower height gain compared to the 50 ppm and 100 ppm concentrations of the third stage of immature oil palm. The smallest oil palm plant height gain was shown in treatment using 150 ppm paclobutrazol concentration, namely D (0.5 kg NPP fertilizer + 150 ppm paclobutrazol), H (6.4 kg palm frond compost + 150 ppm paclobutrazol) and L (12.8 kg of palm frond compost + 150 ppm paclobutrazol).

Experiments with 150 ppm treatment (D = 0.5 kg of NPK fertilizer + 150 ppm paclobutrazol, H = 6.4 kg of oil palm frond compost + 150 ppm paclobutrazol, L = 12.8 kg of oil palm frond compost + 150 ppm paclobutrazol)

Table 1. Plant height gain of the third stage of immature oil palm with the addition of palm frond compost and paclobutrazol at 2 MAT, 4 MAT and 6 MAT (cm).

Treatment	The average increase in plant height (cm)		
	2 MAT	4 MAT	6 MAT
A	6.97 ^{a}	27.53 ^{a}	41.20 ^{a}
B	6.23 ^{b}	26.27 ^{b}	38.87 ^{b}
C	5.73 ^{b}	25.73 ^{b}	37.43 ^{b}
D	4.97 ^{c}	23.60 ^{c}	32.93 ^{c}
E	6.73 ^{a}	28.63 ^{a}	41.77 ^{a}
F	5.97 ^{b}	26.20 ^{b}	39.07 ^{b}
G	5.77 ^{b}	25.77 ^{b}	37.60 ^{b}
H	5.07 ^{c}	23.70 ^{c}	32.73 ^{c}
I	6.60 ^{a}	30.37 ^{a}	41.33 ^{a}
J	5.97 ^{b}	26.83 ^{b}	38.83 ^{b}
K	5.77 ^{b}	25.87 ^{b}	36.57 ^{b}
L	4.83 ^{c}	23.77 ^{c}	32.67 ^{c}

Note: Values in the same column and row followed by different notations show significantly different (p<0.05) based on the 5% Scott Knott test

Table 2. Stem circumference gain of the third stage of immature by giving compost from palm fronds, and paclobutrazol at 2 MAT, 4 MAT and 6 MAT (cm).

Treatment	Average gain in stem circumference (cm)		
	2 MAT	4 MAT	6 MAT
A	3.60 ^{b}	7.33 ^{b}	13.60 ^{b}
B	3.67 ^{b}	7.50 ^{b}	14.33 ^{b}
C	3.77 ^{b}	7.60 ^{b}	14.93 ^{b}
D	3.93 ^{a}	8.23 ^{a}	14.90 ^{b}
E	3.50 ^{b}	7.13 ^{b}	13.97 ^{b}
F	3.53 ^{b}	7.17 ^{b}	14.03 ^{b}
G	3.67 ^{b}	7.43 ^{b}	14.43 ^{b}
H	3.73 ^{b}	7.53 ^{b}	14.70 ^{b}
I	3.57 ^{b}	7.37 ^{b}	14.67 ^{b}
J	3.63 ^{b}	7.43 ^{b}	14.63 ^{b}
K	3.87 ^{a}	7.87 ^{a}	15.73 ^{a}
L	4.17 ^{a}	8.50 ^{a}	15.90 ^{a}

Note: Values in the same column and row followed by different notations show significantly different (p<0.05) based on the 5% Scott Knott test showed that there was a decrease in the percentage of height increment by about 20%-21.64% compared to treatment without paclobutrazol. The increase in oil palm height at 6 MAT was around 32.67- 41.77 cm or about 5.45-6.96 cm/month. According to (14), the stem height of oil palm plants increases by approximately 35-75 cm per year or an average of 2.9-6.25 cm per month, so it can be concluded that the application of paclobutrazol in the third stage of immature oil palm still provides a suitable height increase in oil palm growth.

Research showed that there has been a high inhibition caused by a reduction in assimilates for plant vegetative growth and diverted to the generative or flowering phase. Those were by (15) stated that paclobutrazol can reduce the rate of cell division so that it will inhibit plant vegetative growth so that the photosynthate produced will divert to the generative phase that is needed for the formation of plant flowers.

Stem circumference

This study showed that treatments A (500 g NPK fertilizer + without paclobutrazol), B (500 g NPK fertilizer + 50 ppm paclobutrazol), C (500 g NPK fertilizer + 100 ppm paclobutrazol), E (4 kg palm frond compost + without paclobutrazol), F (6.4 kg of oil palm frond compost + 50 ppm paclobutrazol), G (6.4 kg of oil palm frond compost + 100 ppm paclobutrazol), H (6.4 kg of oil palm frond compost + 150 ppm paclobutrazol), I (12.8 kg of oil palm frond compost + without paclobutrazol) and J (12.8 kg of oil palm frond compost + 50 ppm paclobutrazol) were not significantly different in oil palm stem circumference gain at 2 MAT, 4 MAT and 6 MAT.

The application of the palm frond compost can provide an increase in stem circumference that is equivalent to the use of 500 g NPK inorganic fertilizer. The increase in stem circumference at 2-4 MAT indicated treatment D (500 g NPK + 150 ppm paclobutrazol), K (12.8 kg palm frond compost + 100 ppm paclobutrazol), L (12.8 kg palm frond compost + 150 ppm paclobutrazol) had the highest stem circumference gain compared to the other treatments. The increase in stem circumference at 6 MAT showed the highest results in the K and L treatments compared to other treatments.

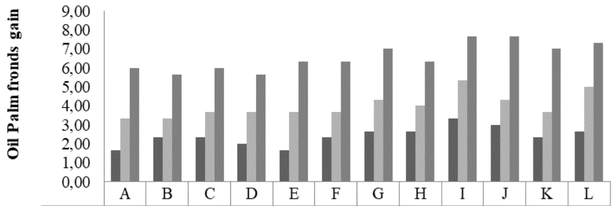
Table 2 shows that the treatments D (500 g NPK + 150 ppm paclobutrazol), K (12.8 kg palm frond compost + 100 ppm paclobutrazol), L (12.8 kg palm frond compost + 150 ppm paclobutrazol) produce the best effect in increasing the diameter of oil palm trunks at 2 MAT and 4 MAT. This indicates that the application of 12.8 kg oil palm frond compost combined with 100 ppm and 150 ppm paclobutrazol gives an effect equivalent to the application of 500 g of NPK fertilizer with a combination of 150 ppm paclobutrazol. The combination of oil palm frond compost and paclobutrazol is thought to play a role in increasing the oil palm stems.

The best treatment at 6 MAT was K (12.8 kg of oil palm frond compost + 100 ppm paclobutrazol and L (12.8 kg of oil palm frond compost + 150 ppm paclobutrazol). Combined with 100 ppm and 150 ppm, paclobutrazol worked synergistically in enlarging plant stems. A dose of 12.8 kg of oil palm frond compost was thought to be able to provide higher amounts of nutrients than the other doses of frond compost. Increasing the dose of organic matter without the addition of NPK fertilizer was able to increase plant growth in areas such as height, stem diameter and leaf chlorophyll (16).

Stem circumference greatly affects the number of fruits in oil palm. Indirectly, the number of fruits is influenced by the number of flowers that grow on oil palm plants. The larger the size of the stem circumference, the more flowers and fruit it produces (17).

Number of palm fronds

The combination treatment of oil palm frond compost and paclobutrazol had no significant effect on treatments 2, 4, and 6 MAT. This shows that the use of oil palm frond compost provides an equivalent increase in the number of fronds compared to the use of 500 g of NPP fertilizer. According to (18), oil palm fronds can grow as many as 22 fronds per year, equivalent to 1.8 per month. As shown by (19), the growth of oil palm fronds of the Simalungun variety was around 1.17-1.67 fronds per month. As can be seen in Fig. 1, the results showed that the number of fronds growing was about 1.0-1.3 per month, but the value



	A	B	C	D	E	F	G	H	I	J	K	L
2MAT	1,67	2,33	2,33	2,00	1,67	2,33	2,67	2,67	3,33	3,00	2,33	2,67
4MAT	3,33	3,33	3,67	3,67	3,67	3,67	4,33	4,00	5,33	4,33	3,67	5,00
6MAT	6,00	5,67	6,00	5,67	6,33	6,33	7,00	6,33	7,67	7,67	7,00	7,33

Fig. 1. Oil palm fronds gain of the third stage of immature with the addition of oil palm fronds compost and paclobutrazol at 2 MAT, 4 MAT and 6 MAT.

of the added fronds in this study was still smaller than that in the previous research.

The difference in the concentration of paclobutrazol did not have a significant effect on the growth of oil palm fronds. This was because paclobutrazol probably only inhibited the gibberellin hormone associated with height growth and did not affect the number of leaves. As stated by (20), paclobutrazol is a retardant that can reduce the rate of stem elongation without affecting leaf growth and development.

This was presumably because the increased dose of oil palm frond compost provided higher levels of nutrients so that photosynthesize ran optimally and produced optimal assimilate, which was distributed to all parts of the plant for proper plant organ formation, including the addition of oil palm frond.

Oil palm frond compost as organic fertilizer can improve soil physical properties, such as increasing water and nutrient absorption and improve soil chemical properties so that nutrient availability increases both macronutrients and micronutrients. This can stimulate photosynthesis so that plants are able to produce compounds that can optimize plant growth, one of which is the number of fronds (21).

The addition of a large leaf frond in oil palm increased the potential for more flowers to appear. According to (22), male and female flowers have the potential to emerge from each oil palm frond. Flower sheaths will usually emerge from the fourth circle in the axil of the leaf sheath. The fourth circle is calculated from the youngest circle of the leaf frond from the top of the oil palm (23). The more oil palm fronds, the more flowers will emerge from the axils of the palm fronds.

Leaf area

This study showed that the increase in leaf area tends to be good in treatment I (12.8 kg of oil palm frond compost + without paclobutrazol), as shown in Fig. 2. This is presumably because the use of oil palm frond compost is able to improve the soil physical properties causing the soil to be looser, thus facilitating the absorption of water and nutrients by plant roots and then distributed to plant leaves for photosynthesis (24).

The research showed that the paclobutrazol treatment resulted in a smaller leaf area compared to the treatment without paclobutrazol application. This can be seen in Fig. 2 of treatments D, H and L, which used the highest dose of paclobutrazol (150 ppm) in the experiment. The function of paclobutrazol as an inhibitor that can inhibit plant growth, including inhibiting leaf area growth.

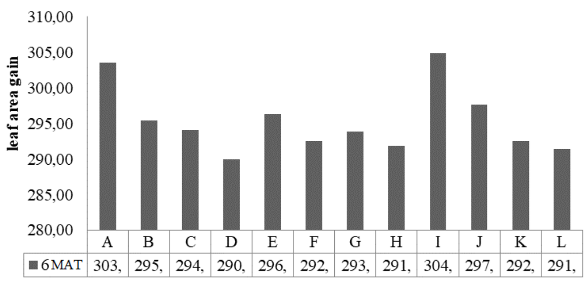


Fig. 2. Leaf area gain of the third stage of immature palm leaf with the addition of palm frond compost and paclobutrazol at 6 MAT.

According to (25), the application of retardant (paclobutrazol) can inhibit the synthesis of gibberellins so that the function of the hormone gibberellins in increasing plant leaf area will be inhibited.

The use of paclobutrazol causes gibberellin inhibition in plants and the elongation of plant cells are inhibited; this causes the leaf size to be smaller compared to plants without paclobutrazol treatment (26). The inhibition of plant leaf area is thought to indicate the plant is entering the generative phase. The application of paclobutrazol can inhibit plant vegetative growth (leaf area) and stimulate the induction of flowering in plants (27).

The chlorophyll content

The results showed that the chlorophyll content in the paclobutrazol treatment at the same dose of palm frond compost or inorganic fertilizers tended to be high compared to the treatment without paclobutrazol. A high increase in chlorophyll content was found in treatment L (12.8 kg palm frond compost + 150 ppm paclobutrazol), as shown in Table 3, with an index of initial chlorophyll content of 21.63 at 0 MAT and 38.93 at 6 MAT.

Table 3. The chlorophyll content of the third stage of immature oil palm by giving compost from palm fronds and paclobutrazol at 0 MAT and 6 MAT.

Treatment	0 MAT	6 MAT	Increase in palm oil chlorophyll
A	29.47	45.52	16.05
B	24.24	41.19	16.95
C	25.82	42.01	16.19
D	25.45	42.19	16.74
E	24.69	37.24	12.55
F	35.33	48,48	13.14
G	31.00	43.78	12.78
H	22.85	36.10	13.25
I	25.99	42.50	16.51
J	21.94	39.01	17.07
K	35.00	51.66	16.66
L	21.63	38.93	17.30

Note: Value showed without notation as no significant difference ($p<0.05$) based on 5% Scott Knott test

The provision of nutrients by oil palm frond compost and the use of paclobutrazol work synergistically in increasing the chlorophyll content of plants. As stated by (28), the application of paclobutrazol was able to reduce overgrowth, increase the chlorophyll content and carotene content of the leaves and increase photosynthetic efficiency and resistance to environmental stress.

The synthesis of chlorophyll in leaves is influenced by various factors, namely light received by the leaves, carbohydrates, water, temperature, genetic factors and nutrients such as N, Mg, Mn, Fe, Cu, Zn, S and O (29). According to (30), leaf chlorophyll content will affect the photosynthesis process. A small amount of chlorophyll will result in the photosynthesis process being suboptimal and affect plant growth and development. Measurement of leaf chlorophyll content during the experiment was carried out at the beginning and end of the study using a chlorophyll meter on the fourth leaf of each plant.

The increase in chlorophyll content that occurs due to the use of paclobutrazol is thought to accelerate the initiation of flowering. As stated by (31), the use of paclobutrazol will result in an increase in chlorophyll content, which will indirectly affect plant flowering.

Flowering initiation

The combined application of oil palm frond compost and paclobutrazol did not show the appearance of a flower sheath in the axillary of the third stage of immature oil palm frond during observations. The result of this study has shown that vegetative growth in the form of plant height with paclobutrazol treatment appears to have a smaller increase than without paclobutrazol. This is presumably because photosynthate has been channeled to lateral growth and will spur the generative growth of plants.

As stated by (32), paclobutrazol can inhibit the performance and biosynthesis of gibberellins and energy flow to the mitochondria, so that it will shorten vegetative growth and will indirectly be diverted for generative growth.

The results indicate the characteristics of flowering in plants where the vegetative phase begins to slow down, such as increases in height, stem circumference, number of leaf midribs and leaf area, while chlorophyll begins to increase.

Conclusion

The results of this experiment showed that all treatments did not produce flower sprouts. The application of oil palm frond compost and paclobutrazol on the third stage of immature oil palm plants gave significantly different effects on the parameters of plant height and circumference and had no significant effect on the parameters of increasing the number of fronds, increasing leaf area, chlorophyll and increasing oil palm flowers. The application of 12.8 kg of oil palm frond compost and 150 ppm of paclobutrazol (treatment L) gave the best effect in inhibiting the height and enlarging the circumference of the third stage of immature oil palm. In this case, the use of paclobutrazol is able to inhibit plant vegetative growth, which indicates the initiation of flowering. The application of the treatment is expected to shorten the initiation of flowering time of 3rd stage of immature oil palm, which, presumably due to the plantation altitude (780 m above sea level) is not aligned with the recommended altitude (0-500 m above sea level). Further study can be suggested to analyze how long the flower initiation time can be shortened.

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Authors' contributions

MA conducted the research design, outlined the overall study, general coordination and corresponding to the editor. HKB performed the field treatments of the research, data collection and drafted the manuscript. MAS and CSVZ performed the statistical analysis and reviews. YA performed the manuscript alignment with research design and results. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None.

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