Response of four oil palm varieties to low frond desiccation in the main nursery with water stress conditions on peat

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Abstract. Oil palm is an important commodity for plantation sub-sector in Indonesia. The limitation of mineral soils for agriculture directs utilization of peatland for oil palm plantation. The major problem of peatland plantations is Low Frond Desiccation (LFD) due to fluctuation of groundwater. This study observed the responses of oil palm in the main nursery to water stress as well as the changes in physical and physiological properties of plants. This research using factorial randomized block design, replicated three times with two factors (four oil palm varieties and five watering stoppage) to determine plant responses to watering stoppage. The results showed that watering stoppage can increase the LFD incidence, decrease leaf chlorophyll, water content and plant height. The highest incidence and LFD intensity was at 5 weeks watering stoppage with the highest LFD intensity value of 45.67%. LFD started at 2 weeks watering stoppage with LFD intensity ranging from Dumpy variety 17.69%, DxP 540 variety 28.58%, Langkat variety 29.46%, Yangambi variety 38.89%. The oil palm varieties having the highest LFD intensity at 5 weeks watering stoppage were found in the Yangambi variety and the lowest was in the Dumpy variety.

1. Introduction
Oil palm is an important commodity of the plantation sub-sector in Indonesia. The increasing demand for bioenergy raw materials has led to an increase in land use intensity [1]. The expansion of oil palm plantations on peatlands is growing rapidly on the islands of Sumatra and Kalimantan, while in Papua the cultivation on peatlands is relatively underdeveloped. Of the three islands, the area of oil palm plantations on peat land increased from around 0.23 million hectares to 1.50 million hectares in 2010 [2].

Peat soil is formed in situ from the accumulation of dead plant debris (logs, twigs, and roots) for thousands of years. The rate of deposition is faster than decomposition due to the anaerobic atmosphere of the water-saturated environment [3]. Tropical peat soils naturally have a very high water-binding capacity which is related to the number of macropores and very high porosity [4].

Peatland should be protected and managed systematically in an integrated manner to conserve its functions while preventing the damage of the ecosystem. Peatland management is focused on saving the function of the peat ecosystem, both for cultivation and protection [3].

Cultivation of oil palm on peat land faces various limiting factors for its growth, such as high acidity, relatively low soil fertility, easy-to-dry nature of peat soils, and low bulk density. The development of
oil palm on peatlands needs drainage by making channels to lower the water table and create a suitable root space for oil palm plants, that allows the growth and production of the plants [5,6]. However, sometimes excessive drainage encourages peat soil to dry up and causes hydrophobicity or the emergence of irreversible dryness [7].

Several research stated that the deep fluctuation of the peat soil surface, apart from causing hydrophobicity, it may affect the increase in soil CO₂ emissions [8,9], peat surface decline [10], oil palm growth and production, as well as degrading soil properties [6,9].

Decreasing groundwater levels and water stress will affect nutrient transportation, assimilation processes and physiological cycles [11]. The incidence of LFD in oil palm plants reduces production up to 27% during one year, and declining number of bunches by almost 30% in a year [12]. The decreasing number of bunches is due to the water stress, which affects flower abortion, bunch failure, increased male flower formation and decreased female flower formation [13].

2. Materials and method
This research was conducted at Aek Pancur Nursery at Tanjung Morawa Oil Palm Research Center, Medan and the soil analysis were carried out at Medan Palm Oil Research Center Laboratory. The materials included Yangambi variety, DxP 540 variety, Langkat variety, Dumpy variety oil palm seedlings, sapric peat planting media originating from the east coast of Sumatera in Panai Jaya garden of PT. Perkebunan Nusantara IV, compound fertilizer NPKMg (15.15.6.4), insecticide and fungicide.

This experiment was two factor factorial randomized block design (RBD) with 3 replications. The first factor was Yangambi Variety, DxP 540 Variety, Langkat Variety and Dumpy Variety the second factor was watering stoppage, namely: Control, 2 weeks, 3 weeks, 4 weeks and 5 weeks, thus composed of 20 treatment combinations. The parameters observed were LFD incidence, LFD intensity, leaf chlorophyll analysis (SPAD unit), Water Content (g/100 g peat), and plant height (cm).

3. Data analysis
Analysis of variance was performed to examine the response of four oil palm varieties in the main nursery on the stopping of watering each week. Significant result of analysis will be followed with the Duncan’s multiple range test (DMRT) at the 5% significance level to determine the best variety following the procedure of Gomez and Gomez [14].

4. Results and discussion
The incidence of Low Frond Desiccation was observed in the stoppage watering treatment as control, 2 weeks, 3 weeks and 4 weeks and 5 weeks on four varieties of oil palm plants. It was found there was an incidence of Low Frond Desiccation (LFD) in every week. The morphology of oil palm plants with watering stops is presented in Figure 1.
Figure 1. Oil Palm Morphology due to LFD incidents with a 4 week of watering stoppage (PP4) on four oil palm varieties, (a) Yangambi Variety; (b) DxP 540 Variety; (c) Langkat Variety; (d) Dumpy Variety.

High C-organic content in peat affect the ability of soil to retain water either directly or indirectly [15]. C-organic has the ability to absorb water 20 times of its time[16] therefore at the stop of watering 2 weeks up to 4 weeks there was no morphological change of plant since water was available but decreasing at watering stops of 5 weeks.

4.1. Intensity of low frond desiccation (LFD)

The response of four oil palm varieties with watering stoppage significantly affect the LFD intensity. LFD intensity occurred in all water stress on peat media (Table 1).

| Variety     | Watering stoppage treatment | Control | 2 weeks | 3 weeks | 4 weeks | 5 weeks | Average |
|-------------|----------------------------|---------|---------|---------|---------|---------|---------|
| Yangambi    |                            | 28,33 d | 38,89 c | 17,26 e | 36,18 e | 37,09 c | 31,55   |
| DxP 540     |                            | 16,20 e | 28,58 d | 23,33 d | 23,35 d | 50,98 a | 28,49   |
| Langkat     |                            | 15,81 e | 29,46 d | 30,60 c | 18,44 e | 53,68 a | 29,60   |
| Dumpy       |                            | 16,01 e | 17,69 e | 27,41 d | 33,43 c | 40,95 b | 27,10   |
| **Average** |                            | 19,09 c | 28,66 b | 24,65 b | 27,85 b | 45,67 a | 29,18   |

Note: The numbers in each column followed by the same lowercase letter are not significantly different at the 0.05 DMRT level.

The highest LFD intensity was found in the Yangambi variety with watering stoppage of 31,55%, while the lowest LFD intensity was found in Dumpy variety with watering stoppage of 27,10%. Watering stoppage will decrease the water status of plants leading to drought stress and impacting on biochemical processes of the plant. Consequently, the plant will adapt to the unsuitable environmental conditions by changing their physiological processes and morphology.

The morphological impacts under drought stress are characterized by rotting the tip of the spreading to the middle of the midrib. When the rot reaches the middle, the midrib becomes dry, and finally breaks [17]. The watering stoppage (drought stress) inhibits water and nutrient absorption by plants. In addition, the accumulation of abscisic acid (ABA) of plants experiencing drought stresses increases and the plants automatically close their stomata as an adaptation to reduce transpiration [18].
### 4.2. Chlorophyll analysis

The analysis of variance resulted that watering stoppage and variety affected significantly on the chlorophyll of oil palm leaves (Table 2).

**Table 2.** Chlorophyll analysis (SPAD unit) of four oil palm varieties in the main nursery with watering stoppage treatment.

| Variety   | Water stoppage | Control | 2 weeks | 3 weeks | 4 weeks | 5 weeks | Average |
|-----------|----------------|---------|---------|---------|---------|---------|---------|
| Yangambi  |                | 58,13a  | 55,20b  | 59,50a  | 55,43b  | 49,10d  | 55,47a  |
| DXP 540   |                | 58,83a  | 55,93b  | 48,30d  | 51,63c  | 52,53c  | 53,45b  |
| Langkat   |                | 57,73b  | 58,97a  | 59,57a  | 52,67c  | 49,33d  | 55,65a  |
| Dumpy     |                | 58,30a  | 57,53b  | 59,77a  | 50,67c  | 50,90c  | 55,43a  |
| **Average** |              | 58,25a  | 56,91b  | 56,78b  | 52,60c  | 50,47d  | 55,00   |

Note: The numbers in each column followed by the same lowercase letter are not significantly different at the 0.05 DMRT level.

Table 2 described that watering stoppage has a significant effect to the chlorophyll contents of four varieties of oil palm in the main nursery. The highest chlorophyll content was found in the control, which was 58.25 (unit SPAD), while the lowest chlorophyll content was in the 5 weeks of watering stoppage which was 50.47. The decrease in chlorophyll content in 5 weeks of watering stoppage was due to positive relation between chlorophyll content and the photosynthetic rate. The decrease in photosynthesis due to water stress was also inseparable from the abscisic acid (ABA) which is a signal from the roots that are transported through the xylem vessels and are involved in stomata regulation during drought [19].

### 4.3. Water content

The analysis of variance indicated that watering stoppage had a significant effect on the water content of peat (Table 3).

**Table 3.** Water content (g/100 g) of peatland for four oil palm varieties in the main nursery with watering stoppage.

| Variety   | Water stoppage | Control | 2 weeks | 3 weeks | 4 weeks | 5 weeks | Average |
|-----------|----------------|---------|---------|---------|---------|---------|---------|
| Yangambi  |                | 264,09  | 105,61  | 83,18   | 45,93   | 37,66   | 107,29  |
| DXP 540   |                | 229,53  | 154,60  | 95,33   | 39,16   | 30,63   | 109,85  |
| Langkat   |                | 193,93  | 122,19  | 61,75   | 58,47   | 42,14   | 95,70   |
| Dumpy     |                | 280,17  | 123,64  | 84,83   | 45,56   | 56,15   | 118,07  |
| **Average** |              | 241,93a | 126,51b | 81,27c  | 47,28d  | 41,65d  | 538,64  |

Note: The numbers in each column followed by the same lowercase letter are not significantly different at the 0.05 DMRT level.

It is found that watering stoppage at 2 weeks to 5 weeks may reduce water content in the peat soil. The decrease in soil water content would affect the physiological and biochemical processes of plants. When there is lacking of water, the stomata of the leaves will close so that there is a barrier to the entry of CO₂ and decreases photosynthetic activity. The rate of photosynthesis is closely related to physiological characteristics such as chlorophyll content [20].
4.4. Plant height

The analysis of variety showed that watering stoppage combined with the use of four varieties had a significant effect on the height of the oil palm in the main nursery (Table 4).

Table 4. Plant height (cm) in four varieties of oil palm in the main nursery with watering stoppage treatment.

| Variety   | Water stoppage | Control | 2 weeks | 3 weeks | 4 weeks | 5 weeks | Average |
|-----------|----------------|---------|---------|---------|---------|---------|---------|
| Yangambi  |                | 119.33  | 150.00  | 145.33  | 163.33  | 150.33  | 145.67 b|
| DxP 540   |                | 151.67  | 154.33  | 167.00  | 165.00  | 159.33  | 159.47 a|
| Langkat   |                | 140.67  | 158.00  | 153.33  | 156.67  | 167.00  | 155.13 a|
| Dumpy     |                | 130.67  | 157.00  | 151.33  | 141.00  | 150.67  | 146.13 b|
| Average   |                | 135.58 b| 154.83 a| 154.25 a| 156.50 a| 156.83 a| 151.60  |

Note: The numbers in each column followed by the same lowercase letter are not significantly different at the 0.05 DMRT level

Table 4 described that the varieties oil palm was significantly different in heights. The highest height was in the DxP 540 variety, which was 159.47 cm and the lowest was in the Dumpy variety, which was 146.13 cm. The Dumpy variety was superior comparing to the Yangambi variety.

The watering stoppage on four varieties of oil palm in the main nursery had a significant effect on plant height. The difference in plant height was due to the water stress of the plant, where at 2 weeks of watering stoppage and 5 weeks of watering stoppage the water supply from the peat soil media decreased which resulted in reducing water absorption. This drought stress inhibited the growth of shallow roots, since the cells did not maintain the turgor required for elongation. Deeper roots at the surrounding moistened soil for continuing the grow of the plants. Thus, the root system reproduced itself to maximize soil water content [7,12].

5. Conclusion

LFD in four varieties of oil palm plants in the main nursery with watering stoppage at various levels, namely 2 weeks, 3 weeks, 4 weeks and 5 weeks triggered a decrease in water content, nutrient availability and inhibited oil palm plant height in all varieties. The highest incidence of LFD intensity was at 5 weeks watering stoppage with the highest LFD intensity at 45.67%. LFD started at 2 weeks watering stoppage with LFD intensity ranging from Dumpy variety 17.69%, DxP 540 variety 28.58%, Langkat Variety 29.46%, Yangambi variety 38.89%. The oil palm varieties having the highest LFD intensity at 5 weeks watering stoppage were the Yangambi variety and the lowest was the Dumpy variety.

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