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The Evaluation of Two Oil Palm Clones Response to Nutrient Deficiency Treatment

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ABSTRACT

Advancements in plant physiology, molecular biology, and genetics have enhanced understanding of oil palm responses to nutrient stress. This study evaluated two clones (CPS1 and CPS2) under nutrient-deficiency treatments (N0 P0 K0, N0 P1 K1, N1 P1 K1 [Control], N1 P0 K1, N1 P1 K0). Nutrient deprivation reduced growth, chlorophyll content, and physiological efficiency in both clones. CPS1 showed superior growth and photosynthetic performance, with a higher net photosynthetic rate (11.72 vs. 9.96 µmol CO_2 m^{-2} s^{-1}), greater intercellular CO_2 exchange (0.0396 vs. 0.0346 mol m^{-2} s^{-1}), and higher Ci/Ca ratio (0.348 vs. 0.326). In contrast, CPS2 exhibited greater water use efficiency (3.54 vs. 3.43 µmol m^{-2} s^{-1}) and intrinsic WUE (51.76 vs. 45.03 µmol mol^{-1}), reflecting stronger stomatal adjustment to nutrient stress. CPS1 maintained higher transpiration (3.48 vs. 2.92 mmol H_2O m^{-2} s^{-1}), stomatal conductance (0.28 vs. 0.23 mol H_2O m^{-2} s^{-1}), and leaf water potential (6.51 vs. 5.63 ψ), while both clones shared similar F_v/F_m values (0.76), indicating consistent photochemical efficiency. Morphologically, CPS1 developed more fronds (13 vs. 10) and greater height (117.7 vs. 94.7 cm), while CPS2 recorded slightly higher chlorophyll content (49.9 vs. 49.5). Nitrogen deficiency most strongly limited photosynthesis in both clones. Despite reduced performance under nutrient stress, both clones displayed physiological and morphological adjustments that highlight their capacity to tolerate nutrient-poor environments, with CPS1 excelling in growth and photosynthesis and CPS2 in water use efficiency.

Keywords: Morphophysiological responses, nutrient stress, oil palm clones, photosynthesis, physiological characteristics

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INTRODUCTION

Originating from West Africa, the oil palm (*Elaeis guineensis*) has become a key contributor to Malaysia's GDP (Kushairi et

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al., 2017), with recent gains in yield despite challenges such as declining export demand and lower CPO prices (Parveez et al., 2024). However, productivity is constrained by low soil fertility, nutrient losses, and stress from pests, weeds, and climate factors (Murdi et al., 2023). Optimising nutrient use efficiency is thus critical for sustainable agriculture and food security (Hawkesford & Barraclough, 2011). Oil palms require balanced NPK fertilisation for growth, stress tolerance, and physiological regulation (Adileksana et al., 2020). Seedlings adapt to stress via physiological adjustments, and seed modification offers potential to improve nutrient uptake, drought tolerance, and yield (Rasid et al., 2020). To further enhance productivity, MPOB developed clonal palms such as CPS1, yielding >30 t FFB ha^{-1} (Tarmizi et al., 2017), and CPS2, capable of up to 35.7 t FFB and 10.8 t oil ha^{-1} at high density (Zamzuri, 2011). This study examines clonal responses to nutrient deficiency by assessing physiological, biochemical, and adaptive mechanisms to identify resilient genotypes for sustainable oil palm production.

MATERIALS AND METHODS

Study Design

The study was conducted at MPOB Kluang research station, located in the northern region of Johor (N 2°27’10.0” E 102°45’25.0”). The experiment was performed in an open nursery. Five levels of fertilizer were used in the treatment: N0 P0 K0, N0 P1 K1, N1 P1 K1 (Control), N1 P0 K1 and N1 P1 K0.

Planting Materials

The experiment used two oil palm clones, P164 (CPS1) and P126 (CPS2), generated from tissue culture for genetic homogeneity. Rooted plantlets were cultivated in jiffy pots for three months in the nursery before being transported to 6 × 9 polybags at the study site in the fourth month.

Physiological and Growth Measurements

Leaf gas exchange was measured on fully expanded leaf two using a LI-6400XT system (Li-COR Inc., USA) between 9:00–11:00 a.m., recording net photosynthesis (A), stomatal conductance (g_s), transpiration rate (E), and water use efficiency (WUE = A/E). The cuvette was set at 30 °C, 60% RH, 400 µmol mol^{-1} CO_2, 500 cm^3 min^{-1} flow, and 800 µmol m^{-2} s^{-1} PPFD. Instantaneous carboxylation efficiency (ICE = A/Ci) was calculated, with Ci/Ca ratio used to assess gas exchange regulation, while intrinsic WUE was determined as A/g_s. Plant height was measured from soil to the tip of the longest leaf, fronds were counted manually, and biomass determined after oven-drying at 70 °C for 48 h; chlorophyll content was recorded using a SPAD-502 meter. Leaf water potential (LWP) was measured on leaf two using a pressure chamber (Model 615), where pressurisation continued until the first water droplet appeared. Chlorophyll fluorescence parameter, F_v/F_m were recorded on leaf two between 8:00–10:00 a.m. using a Handy PEA (Hansatech, UK) after 10 min dark adaptation with clips.

RESULTS AND DISCUSSION

Leaf Gas Exchanges

As shown in Figure 1a–g, CPS1 recorded higher photosynthetic rate (11.72 µmol CO_2 m^{-2} s^{-1}), stomatal conductance (0.28 mol H_2O m^{-2} s^{-1}), transpiration (3.48 mmol H_2O m^{-2} s^{-1}), ICE (0.04 mol m^{-2} s^{-1}), and Ci/Ca (0.75) compared to CPS2, while CPS2 performed slightly better in WUE (3.54 vs. 3.42 µmol m^{-2} s^{-1}) and iWUE (51.76 vs. 45.03 µmol CO_2 mol^{-1} H_2O). The lowest values were observed under nitrogen-deficient treatment (N0 P1 K1), reflecting nitrogen's essential role in photosynthesis through the synthesis of key enzymes such as Rubisco, PEPC, and PPDK. Nitrogen deficiency reduces photosynthetic efficiency, leaf area, and green leaf longevity, ultimately constraining plant productivity (Ober & Parry, 2011). Similar patterns were reported in other crops, where nitrogen fertilisation enhanced WUE and photosynthetic efficiency (Akkamis & Caliskan, 2023), and increased Ci/Ca due to reduced mesophyll metabolic activity rather than stomatal limitations (Kumagai et al., 2009).

Vegetative Measurements

Overall, the number of fronds (Figure 2a) and height (Figure 2b) of CPS1 (13 fronds and 117.7 cm) is greater than CPS2 (10 fronds and 94.7 cm) except for chlorophyl content (Figure 2c). In this study, the nitrogen nutrient had the greatest influence on total frond, height and chlorophyll content for both clonal ramets. Applying nitrogen to oil palm seedlings enhances plant vegetative growth and nitrogen is more available in leaves of many plants than other parts (Ashraf et al. 2017). Nitrogen (N) is crucial for oil palm seedlings as it is a building block for tissue growth and essential components like chlorophyll and nucleic acids. Optimal nitrogen levels enhance growth and development by improving the partitioning of nitrogen in seedlings, leading to better overall growth (Manurung et al., 2024).

Leaf Water Potential (LWP)

Figure 3 shows LWP of CPS1 (6.51 ψ) is higher than CPS2 (5.63 ψ). Leaf water potential is crucial for plant functioning, regulated optimally in drylands to balance water supply and stress tolerance, impacting growth and photosynthesis (Ratzmann et al. 2019).

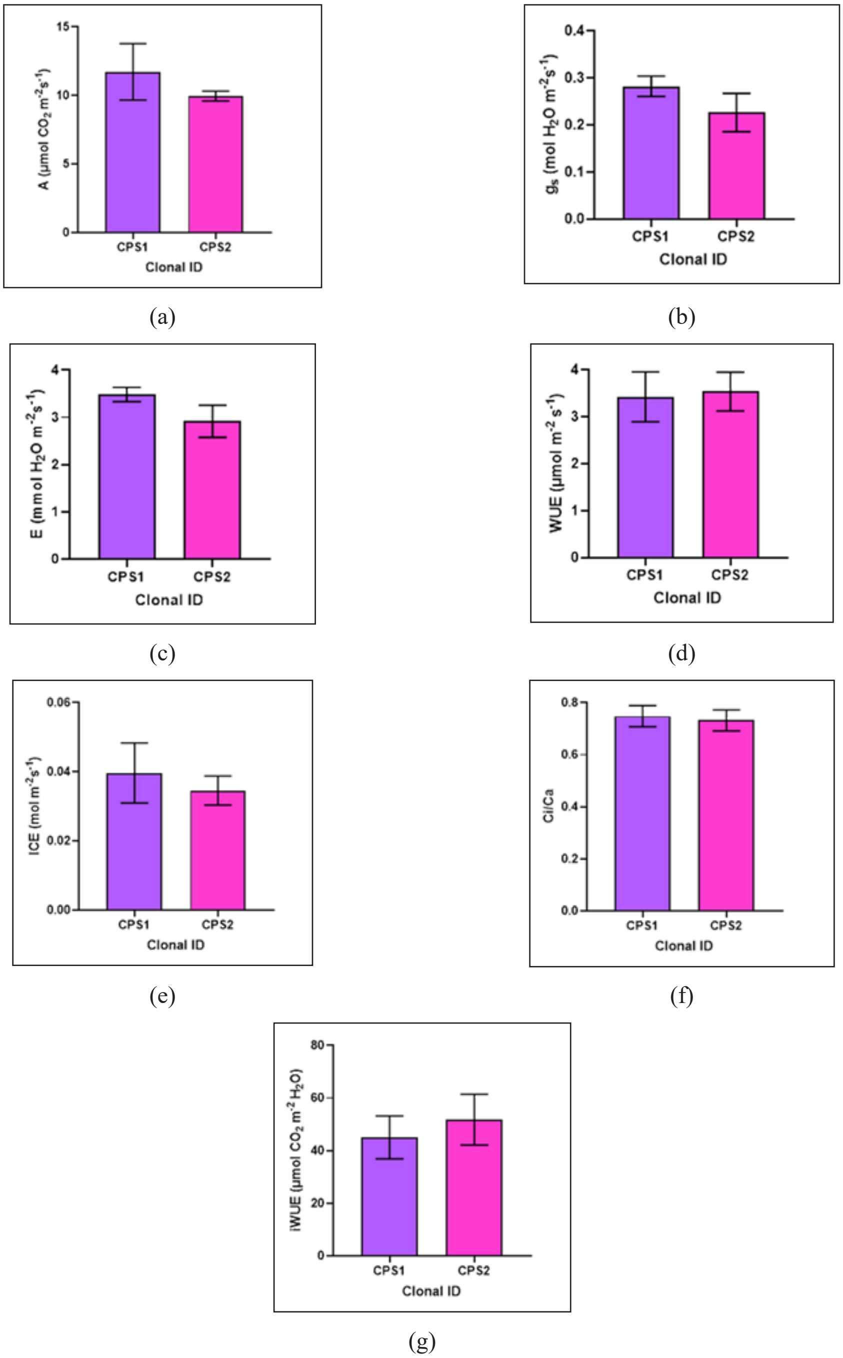

Figure 1. The overall effects of different nutrient stress treatments on the leaf gas exchange of the two clonal oil palm ramets. a) net photosynthetic rate, b) stomatal conductance, c) transpiration rate, d) instantaneous water use efficiency, e) instantaneous carboxylation efficiency, f) ratio of intercellular to ambient CO_2 concentrations, and g) intrinsic water-use efficiency. The bars represent the standard error of mean (SEM) (n =150)

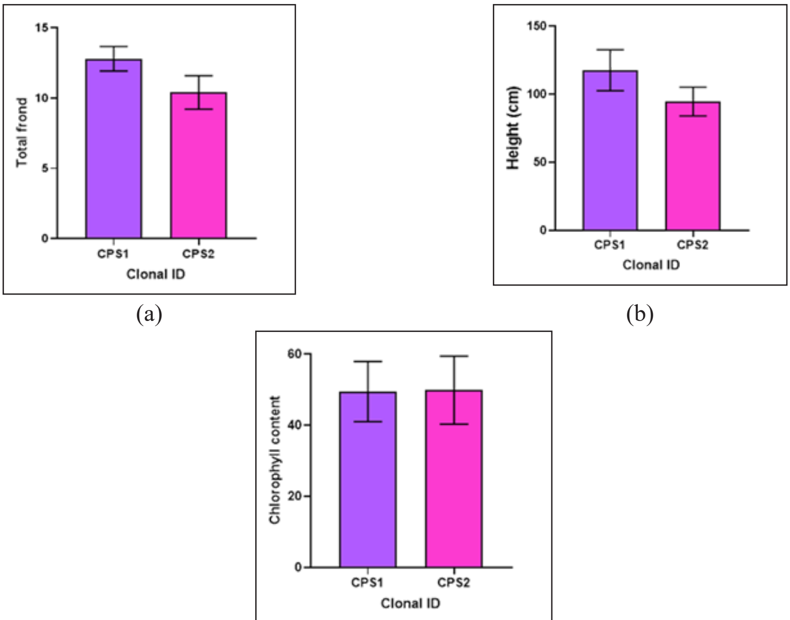

Figure 2. The overall effects of different nutrient stress treatments on vegetative measurement of the two clonal oil palm ramets. a) total frond, b) height of ramets, and c) chlorophyl content. The bars represent the standard error of mean (SEM) (n =150)

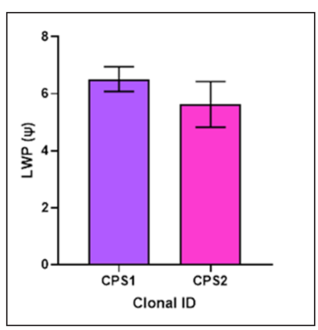

Figure 3. The overall effects of different nutrient stress treatments on leaf water potential of the two clonal oil palm ramets. The bars represent the standard error of mean (SEM) (n =150)

Maximum Efficiency of Photosystem II (F_v/F_m)

Based on Figure 4, both CPS2 and CPS1 demonstrate similar levels of F_v/F_m. The optimum F_v/F_m ratio for many plant species is around 0.79 to 0.84, lower values imply higher plant stress (Wu et al. 2023). The highest mean value result aligns with the research done by Xing & Wu (2014), in which they found that *Pharbitis nil*, a species of climber plant, exhibited a remarkable tolerance to P deficiency. This plant species was able to maintain higher F_v/F_m values even under 0 mM P concentration, indicating that it was able to continue photosynthetic activity in the face of nutrient stress. This suggests that this species can successfully control its photosynthetic system during extended P stress.

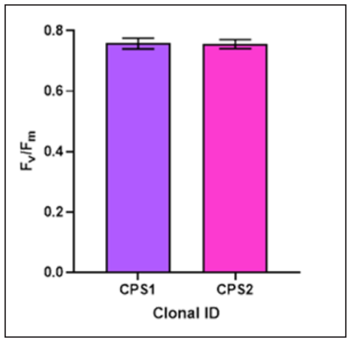

Figure 4. The overall effects of different nutrient stress treatments on the maximum efficiency of photosystem II of the two clonal oil palm ramets. The bars represent the standard error of mean (SEM) (n =150)

CONCLUSION

Overall, this study demonstrates the critical role of nutrient availability in shaping the physiological and morphological responses of oil palm clones, with notable differences between CPS1 and CPS2 under nutrient-deficient conditions. Both clones exhibited tolerance to severe stress through adjustments in growth and physiology; however, CPS1 demonstrated superior growth and photosynthetic performance, whereas CPS2 showed enhanced water use efficiency, indicating divergent adaptive strategies. Among the tested treatments, nitrogen fertiliser had the most pronounced positive effect. These findings provide a foundation for breeding programmes to enhance nutrient use efficiency and resilience, while future research should explore molecular mechanisms and long-term studies to guide sustainable, nutrient-efficient, high-performing oil palm varieties.

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REFERENCES

Adileksana, C., Yudono, P., Purwanto, B. H., & Wijoyo, R. B. (2020). The growth performance of oil palm seedlings in Pre-Nursery and main nursery stages as a response to the substitution of NPK compound fertilizer and organic fertilizer. *Caraka Tani*, *35*(1), 89-97. https://doi.org/10.20961/carakatani.v35i1.33884

Akkamis, M., & Caliskan, S. (2023). Responses of yield, quality and water use efficiency of potato grown under different drip irrigation and nitrogen levels. *Scientific Reports*, *13*(1), Article 9911. https://doi.org/10.1038/s41598-023-36934-3

Ashraf, A. N., Zulkefly, S., Adekunle, S. M., & Samad, M. Y. A. (2017). Growth and biomass yield of oil palm (Elaeis guineensis) seedlings as influenced by different rates of vermicompost. *European Journal of Engineering and Technology Research*, *2*(8), 17-21. https://doi.org/10.24018/ejers.2017.2.8.405

Hawkesford, M. J., & Barraclough, P. (2011). *The molecular and physiological basis of nutrient use efficiency in crops*. John Wiley & Sons.

Kumagai, E., Araki, T., & Ueno, O. (2009). Effect of nitrogen-deficiency on midday photoinhibition in flag leaves of different rice (Oryza sativa L.) cultivars. *Photosynthetica*, *47*(2), 241-246. https://doi.org/10.1007/s11099-009-0038-z

Kushairi, A., Singh, R., & Ong-Abdullah, M. (2017). The oil palm industry in Malaysia: Thriving with transformative technologies. *Journal of Oil Palm Research*, *29*(4), 431-439. https://doi.org/10.21894/jopr.2017.00017

Manurung, A. N. H., Suwarto, Yahya, S., & Nugroho, B. (2024). Nitrogen uptake model of oil palm in main nursery. *Journal of Oil Palm Research, 36*(4), 598-607. https://doi.org/10.21894/jopr.2023.0052

Murdi, A. A., Abidin, N. Z. H. A. Z., Yahya, Z., Nawawi, N. Z., & Hashim, Z. (2023). Balanced fertilizer formation for high oil palm production. *Advances in Oil Palm Research, 1*(2), 195-211.

Ober, E., & Parry, M. A. (2011). Drought and implications for nutrition. In J. Malcolm, Hawkesford & P. Barraclough (Eds.) *The molecular and physiological basis of nutrient use efficiency in crops* (pp. 429-441). John Wiley & Sons, Inc.

Parveez, G. K. A., Leow, S. S., Kamil, N. N., Madihah, A. Z., Ithnin, M., Ng, M. H., Yusof, Y. A., & Idris, Z. (2024). Oil palm economic performance in Malaysia and R&D progress in 2023. *Journal of Oil Palm Research*, *36*(2), 171-186. *Journal of Oil Palm Research*, 36(2), 171–186. https://doi.org/10.21894/jopr.2024.0037

Rasid, O. A., Subhi, S. M., Ayub, N. H., Masli, D. I. A., Bohari, B., Mat Yunus, A. M., & Kadir, A. P. G. (2020). Oil palm transgenic research: Challenges, update, and future outlook. In M. Ithnin & A. Kushairi (Eds.) *The oil palm genome* (pp. 69-81). Springer. https://doi.org/10.1007/978-3-030-22549-0_6

Ratzmann, G., Zakharova, L., & Tietjen, B. (2019). Optimal leaf water status regulation of plants in drylands. *Scientific Reports*, *9*(1), Article 3768. https://doi.org/10.1038/s41598-019-40448-2

Tarmizi, A. H., Zamzuri, I., Kamal, R. M. S., Naqiuddin, M. H., Dalilah A. B., & Ong-Abdullah, M. (2017). *MPOB clonal palm series (P456).* MPOB.

Wu, Q., Zhang, Y., Xie, M., Zhao, Z., Yang, L., Liu, J., & Hou, D. (2023). Estimation of F_v/F_m in spring wheat using UAV-based multispectral and RGB imagery with multiple machine learning methods. *Agronomy*, *13*(4), Article 1003. https://doi.org/10.3390/agronomy13041003

Xing, D., & Wu, Y. (2014). Effect of phosphorus deficiency on photosynthetic inorganic carbon assimilation of three climber plant species. *Botanical Studies*, *55*(1), Article 60. https://doi.org/10.1186/s40529-014-0060-8

Zamzuri, I. (2011, November 18). *Clonal propagation programme.* [Paper presentation]. International Seminar on Breeding for Sustainability in Oil Palm, Malaysia.