



UNIVERSITI PUTRA MALAYSIA

**CARBON DIOXIDE ENRICHMENT EFFECTS ON GROWTH AND PHYSIOLOGICAL
ATTRIBUTES OF OIL PALM (*ELAEIS GUINEENSIS* JACQ.) SEEDLINGS**

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By

MOHD HAFIZ BIN IBRAHIM

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
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Science**

June 2008



DEDICATION

For my beloved mother Sharifah bte Hassan, for all of your sacrifices and hardships in caring and teaching me as your son, you have raised me excellently. And for everyone who believed in me, without you there would be no excuses for me to stand still and work hard to achieve my dreams. My heartfelt gratitude for all love, encouragement and support through the years of my quest for knowledge. May this achievement shall be our stepping stone towards living our dreams and ambitions.....

The vegetation of a good land comes forth (easily) by the Permission of its Lord; and that which is bad, brings forth nothing but (a little) with difficulty. Thus do We explain variously the Ayât (proofs, evidences, verses, lessons, signs, revelations, etc.) for a people who give thanks”.

“[Al-A’râf 7 : 58]



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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Chairman : Associate Professor Hawa ZE Jaafar, PhD

Faculty : Agriculture

The demand for *Elaeis guineensis* Jacq. (oil palm) seedlings keeps increasing by the years due to an increased need in replanting of palms over the age of 25 years. In 2006, about 89% of oil palm area was under mature palms. However, replanting of oil palm is faced with major constraint due to the long period of seedling establishment, which usually takes about 11 – 12 month in nursery before seedlings can be transplanted out to the field. Subsequently, cost of seedling establishment and nursery management remains high and economic pay back slows due to relatively late bearing. Development of a new technique that can enhance seedling growth and reduce nursery period would mean generation of high income to oil palm propagators and growers. One possible way to enhance seedling growth and development is by CO₂ enrichment although responses to CO₂ enrichment can be species dependent. Therefore, the main objective of the study was to examine the effects of CO₂ enrichment on the growth and physiological responses of three progenies of oil palm seedlings. It was hypothesized that CO₂-enriched palms

would increase their relative growth rate (RGR) and total biomass through the enhanced of water use efficiency (WUE) and net photosynthesis (A). In accomplishing the research, two experiments were carried out bearing the following specific objectives, namely: 1) to investigate the effects of different CO₂ concentrations on seedling growth, leaf gas exchange and macronutrients status of three oil palm progenies; and; 2) to examine the effects of different durations of CO₂ enrichment on growth of oil palm seedlings.

In experiment one, three *tenera* progenies of oil palm seedlings, *Deli Urt*, *Deli Yangambi* and *Deli AVROS* were exposed to three levels of CO₂ enrichment viz ambient CO₂ (control) twice ambient carbon CO₂ (800 µmol/mol) and thrice ambient CO₂ (1200 µmol/mol). The enrichment treatments were carried out continuously for six days per week between 0800 to 1000am for 15 weeks. Treatments were arranged in a Split Plot RCBD design replicated three times. Each treatment consisted of 10 palms with CO₂ levels as the main plot and progenies, as the subplot. Results showed there were no interaction between CO₂ and progenies enrichment neither were there preference for CO₂ by the progenies observed. However, CO₂ imposed ($p \leq 0.05$) a very marked effect on the growth and the leaf gas exchange parameters although all the variables measured did not differ significantly when palms were exposed to 800 and 1200 µmol/mol of CO₂. Exposing seedlings to higher (800 µmol/mol) CO₂ concentration resulted in higher total biomass, net assimilation rate (NAR), RGR, plant height, frond number, basal diameter and total leaf area compared to the controlled seedlings. As further

increase in CO₂ concentration (1200 µmol/mol) occurred, seedlings become acclimatized to increased quantum efficiency of PSII (F_v/F_m). However total chlorophyll content and stomata density (pores/mm²) reduced. Higher CO₂ concentration than ambient affected leaf gas exchange. Upon enrichment, net photosynthesis (A) and WUE increased, but there was reduction in stomata conductance (g_s) and evapotranspiration rate (E). Increase in WUE under increased CO₂ concentration implied that plant could utilize water per unit carbohydrate produced especially when undergoing stress. Seedlings treated with high CO₂ increased their apparent quantum yield (α) and A_{max} but light compensation point was reduced.

Nutrient analysis from leaves showed that oil palm seedling treated with high CO₂ are deficient in nutrients compared to control. Total N, P, K, Ca and Mg were significantly reduced ($p \leq 0.05$) in all the CO₂ treatments but total carbon and C:N ratio increased. Enrichment with 800 µmol/mol CO₂ was most efficient in enhancing growth and photosynthetic traits of oil palm seedlings although there was no significant difference between the three progenies. Result suggested, that enrichment with CO₂ could improve growth of oil palm seedling. The study also proved that a two-hour straight fertilization with CO₂ was able to enhance the growth of oil palm seedlings by increasing the photosynthetic rate, WUE and apparent quantum yield (α).

In the second experiment, seedlings were exposed to different duration of CO₂ enrichment viz: two hours (0800 – 1000; Control), three hours (0800 – 1100), and four hours (0800 – 1200) at 800 µmol/mol CO₂. The treatments

were arranged in Randomized Complete Block Design (RCBD) replicated three times, and each treatment consisted of 12 palms. There was no significant difference in frond number, total chlorophyll contents, plant height, basal diameter, leaf area, total plant biomass, leaf area ratio, leaf weight ratio, shoot to root ratio, NAR and RGR when palms were exposed to different duration of CO₂ enrichment. The result suggested that enrichment for two hours was efficient to enhance growth of oil palm seedling and that further increase in exposure time to CO₂ enrichment did not help to further increase the growth.

The results showed that CO₂ at 800 µmol/mol with 2-hours of exposure was effective in increasing plant growth by increasing total biomass, RGR and NAR by 112, 18 and 70% respectively thus reducing the time for plants to be maintained in the nursery by 4 months.

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**PENGARUH PERKAYAAN KARBON DIOKSIDA TERHADAP
PERTUMBUHAN DAN FISILOGI ANAK KELAPA SAWIT**

Oleh

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Jun 2008

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Permintaan untuk anak pokok kelapa sawit (*Elaeis guineensis* Jacq.) kian meningkat dari tahun ke tahun disebabkan penanaman semula pokok kelapa sawit yang berumur lebih dari 25 tahun. Pada tahun 2006, sebanyak 89% kawasan penanaman kelapa sawit adalah terdiri dari pokok yang telah matang. Walaubagaimanapun, anak benih kelapa sawit mengambil masa lebih kurang 11 -12 bulan dalam tapak semaian sebelum boleh dipindah ke ladang untuk penanaman semula. Di sebabkan ini, kos penjagaan dan pengurusan tapak semaian tinggi dan pusingan modal lambat kerana pokok lambat membesar. Pembangunan teknik yang boleh mengurangkan tempoh masa di tapak semaian akan memberi lebih pulangan pada pengusaha dan pembekal anak pokok kelapa sawit. Satu cara yang dikenalpasti adalah dengan menggunakan teknik perkayaan CO₂ pada bahan tanaman walaupun kesan perkayaan CO₂ bergantung pada spesis pokok. Dengan itu, objektif utama penyelidikan ini ialah untuk menilai kesan perkayaan CO₂ pada pertumbuhan dan fisiologi tiga progeni anak pokok kelapa sawit. Adalah

dihipotesiskan bahawa anak pokok yang diperkayakan dengan CO₂ akan mempunyai kadar pertumbuhan relatif dan jumlah biomass lebih tinggi melalui peningkatan dalam kecekapan penggunaan air (WUE) dan fotosintesis. Dua eksperimen telah dijalankan dengan objektif spesifik iaitu; 1) untuk mengkaji kesan perkayaan pelbagai tahap CO₂ pada pertumbuhan anak pokok kelapa sawit; dan; 2) untuk mempelajari kesan pelbagai tahap tempoh perkayaan CO₂ pada pertumbuhan anak pokok kelapa sawit.

Dalam eksperimen satu tiga progeni tenera kelapa sawit, *Deli URT*, *Deli Yangambi* dan *Deli AVROS* telah didedahkan pada tiga tahap kepekatan CO₂ iaitu (1) persekitaran CO₂ (kawalan); (2) dua kali kepekatan persekitaran (800 µmol/mol) dan (3) tiga kali kepekatan persekitaran (1200 µmol/mol). Perkayaan dilakukan selama enam hari seminggu untuk dua jam dari pukul 0800 -1000 selama 15 minggu. Rawatan disusun dalam rekabentuk Split Plot RCBD direplikasikan tiga kali. Setiap gabungan rawatan terdiri dari 10 anak pokok dimana CO₂ adalah plot utama dan progeni adalah subplot. Secara keseluruhannya, keputusan menunjukkan tiada interaksi antara CO₂ dan progeni dan kesan progeni dalam kesemua parameter yang diperhatikan. Walaubagaimanapun, CO₂ ($p \leq 0.05$) mempengaruhi kesemua parameter fisiologi dan pertumbuhan meskipun, tiada perbezaan ketara antara anak pokok yang diperkayakan dengan 800 dan 1200 µmol/mol CO₂. Anak pokok kelapa sawit yang diperkayakan lebih dari kepekatan persekitaran menunjukkan peningkatan dalam biomas, kadar asimilasi keseluruhan (NAR), kadar pertumbuhan relatif (RGR), tinggi per pokok, nombor pelepah per pokok, diameter pangkal pokok dan luas daun dari pokok kawalan.

Semakin tinggi kepekatan CO₂, pokok meningkatkan keefisyenan maksimum kuantum PSII (F_v/F_m), tetapi jumlah klorofil dan kepadatan stomata (liang/mm²) di dapati menurun. Kepekatan tinggi CO₂ juga mempengaruhi kadar pertukaran gas daun. Semasa perkayaan, fotosintesis dan kecekapan penggunaan air (WUE) meningkat tetapi penurunan berlaku pada kekonduksian stomata (g_s) dan kadar transpirasi (E). Peningkatan dalam keefisyenan penggunaan air menunjukkan pokok boleh menggunakan air secara efisien untuk setiap karbohidrat yang dihasilkan dan boleh menyesuaikan dengan keadaan stress disebabkan kekurangan cahaya seperti yang ditunjukkan dalam keluk tindak balas cahaya yang diukur di dalam eksperimen ini. Anak pokok yang diperkayakan dengan CO₂ mempunyai tinggi hasil kuantum keketara (α) dan A_{max} tetapi titik pampasan menurun.

Analisis nutrien dari daun menunjukkan yang anak pokok kelapa sawit yang diperkayakan mengalami kekurangan nutrien dari pokok kawalan. Keseluruhan N, P, K, Ca dan Mg menurun dalam pokok yang diperkaya dengan CO₂ tetapi jumlah karbon dan C:N ratio meningkat. Perkayaan dengan 800 $\mu\text{mol/lmol}$ CO₂ adalah didapati efisien didalam meningkatkan pertumbuhan dan fotosintesis dalam anak pokok kelapa sawit walaupun tiada perbezaan ketara antara tiga progeni tersebut. Keputusan menunjukkan perkayaan CO₂ mampu mempengaruhi pembesaran anak pokok kelapa sawit. Kajian ini juga menunjukkan yang perkayaan selama dua jam dengan CO₂ mengaruh pembesaran anak pokok dengan meningkatkan kadar fotosintesis, WUE dan kadar kuantum keketara (α).

Di dalam eksperimen kedua, anak pokok telah didedahkan pada tiga durasi CO₂ iaitu: Dua jam (0800 – 1000; Kawalan), tiga jam (0800 – 1100) dan empat jam (0800 – 1200) pada kepekatan 800 µmol/mol CO₂. Rawatan disusun dalam Randomized Complete Block Design (RCBD) direplikasi tiga kali dan setiap gabungan rawatan mempunyai 12 pokok. Keputusan menunjukkan tiada perbezaan ketara antara durasi yang digunakan ($p \geq 0.05$) untuk bilangan pelepah, jumlah klorofil keseluruhan, tinggi pokok, diameter pangkal, luas daun, jumlah biomass, leaf area ratio, leaf weight ratio, nisbah akar ke pucuk, NAR dan RGR pada kesemua parameter pertumbuhan yang diukur. Keputusan menunjukkan yang perkayaan pada dua jam (kawalan) adalah efisien untuk mengaruh pertumbuhan anak pokok kelapa sawit dan pertambahan tempoh masa pada perkayaan CO₂ tidak membantu pertumbuhan.

Keputusan menunjukkan bahawa kepekatan CO₂ pada 800 µmol/mol dengan perkayaan selama dua jam adalah berkesan untuk meningkatkan pertumbuhan pokok kelapa sawit dengan peningkatan jumlah biomass, RGR dan NAR pada 112, 18 dan 70% dengan itu mengurangkan tempoh masa anak kelapa sawit didalam semaian selama 4 bulan.

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I certify that an Examination Committee has met on 18th September 2008 to conduct the final examination of Mohd Hafiz Bin Ibrahim on his Master of Science thesis entitled “Carbon Dioxide Enrichment Effects on Growth and Physiological Attributes of Oil Palm Seedlings”, in accordance with Universiti Pertanian Malaysia (Higher Degree) Act. 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Member of the Examination Committee are as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or and is not concurrently submitted for any other degree at UPM or at any other institutions.

MOHD HAFIZ BIN IBRAHIM

Date : 13 August 2008

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