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 Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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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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June 2008

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 CO_2 enrichment although responses to CO_2 enrichment can be species dependent. Therefore, the main objective of the study was to examine the effects of CO_2 enrichment on the growth and physiological responses of three progenies of oil palm seedlings. It was hypothesized that CO_2-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 CO_2 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 CO_2 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 CO_2 enrichment viz ambient CO_2 (control) twice ambient carbon CO_2 (800 µmol/mol) and thrice ambient CO_2 (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 CO_2 levels as the main plot and progenies, as the subplot. Results showed there were no interaction between CO_2 and progenies enrichment neither were there preference for CO_2 by the progenies observed. However, CO_2 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 CO_2. Exposing seedlings to higher (800 µmol/mol) CO_2 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 CO_2 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/mm^2) reduced. Higher CO_2 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 CO_2 concentration implied that plant could utilize water per unit carbohydrate produced especially when undergoing stress. Seedlings treated with high CO_2 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 CO_2 are deficient in nutrients compared to control. Total N, P, K, Ca and Mg were significantly reduced ($p \leq 0.05$) in all the CO_2 treatments but total carbon and C:N ratio increased. Enrichment with 800 µmol/mol CO_2 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 CO_2 could improve growth of oil palm seedling. The study also proved that a two-hour straight fertilization with CO_2 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 CO_2 enrichment viz: two hours (0800 – 1000; Control), three hours (0800 – 1100), and four hours (0800 – 1200) at 800 µmol/mol CO_2. 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 CO_2 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 CO_2 enrichment did not help to further increase the growth.

The results showed that CO_2 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.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGARUH PERKAYAAN KARBON DIOKSIDA TERHADAP PERTUMBUHAN DAN FISIOLOGI ANAK KELAPA SAWIT

Oleh

MOHD HAFIZ IBRAHIM

Jun 2008

Pengerusi : Profesor Madya Hawa ZE Jaafar, PhD

Fakulti : Pertanian

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 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 mengunakan teknik perkayaan CO_2 pada bahan tanaman walaupun kesan perkayaan CO_2 bergantung pada spesis pokok. Dengan itu, objektif utama penyelidikan ini ialah untuk menilai kesan perkayaan CO_2 pada pertumbuhan dan fisiologi tiga progeni anak pokok kelapa sawit. Adalah

dihipotesiskan bahawa anak pokok yang diperkayakan dengan CO_2 akan mempunyai kadar pertumbuhan relatif dan jumlah biomass lebih tinggi melalui peningkatan dalam kecekapan pengunaan air (WUE) dan fotosintesis. Dua eksperimen telah dijalankan dengan objektif spesifik iaitu; 1) untuk mengkaji kesan perkayaan pelbagai tahap CO_2 pada pertumbuhan anak pokok kelapa sawit; dan; 2) untuk mempelajari kesan pelbagai tahap tempoh perkayaan CO_2 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 CO_2 iaitu (1) persekitaran CO_2 (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 CO_2 adalah plot utama dan progeni adalah subplot. Secara keseluruhannya, keputusan menunjukkan tiada interaksi antara CO_2 dan progeni dan kesan progeni dalam kesemua parameter yang diperhatikan. Walaubagaimanapun, CO_2 ($p \leq 0.05$) mempengaruhi kesemua parameter fisiologi dan pertumbuhan meskipun, tiada perbezaan ketara antara anak pokok yang diperkayakan dengan 800 dan 1200 µmol/mol CO_2. Anak pokok kelapa sawit yang diperkayakan lebih dari kepekatan persekitaran menunjukkan peningkatan dalam biomas, kadar assimilasi 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 CO_2, pokok meningkatkan keefisyenan maksimum kuantum PSII (F_v/F_m), tetapi jumlah klorofil dan kepadatan stomata (liang/mm^2) di dapati menurun. Kepekatan tinggi CO_2 juga mempengaruhi kadar pertukaran gas daun. Semasa perkayaan, fotosintesis dan kecekapan pengunaan 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 efisyen 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 CO_2 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 CO_2 tetapi jumlah karbon dan C:N ratio meningkat. Perkayaan dengan 800 µmol/lmol CO_2 adalah didapati efisyen didalam meningkatkan pertumbuhan dan fotosintesis dalam anak pokok kelapa sawit walaupun tiada perbezaan ketara antara tiga progeni tersebut. Keputusan menunjukkan perkayaan CO_2 mampu pempengaruhi pembesaran anak pokok kelapa sawit. Kajian ini juga menunjukkan yang perkayaan selama dua jam dengan CO_2 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 CO_2 iaitu: Dua jam (0800 – 1000; Kawalan), tiga jam (0800 – 1100) dan empat jam (0800 – 1200) pada kepekatan 800 µmol/mol CO_2. 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 efisyen untuk mengaruh pertumbuhan anak pokok kelapa sawit dan pertambahan tempoh masa pada perkayaan CO_2 tidak membantu pertumbuhan.

Keputusan menunjukkan bahawa kepekatan CO_2 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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Date: 30 December 2008

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date : 15 January 2009

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.

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MOHD HAFIZ BIN IBRAHIM

Date : 13 August 2008

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