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PENGHITUNGAN LAJU RESPIRASI KELAPA SAWIT (*Elaeis guineensis* Jacq.) BERDASARKAN ANALISIS KESEIMBANGAN ASIMILAT

Iman Yani Harahap, Subronto, dan Witjaksana Darmosarkoro

ABSTRAK

Untuk mengetahui peran aspek respirasi dalam proses pertumbuhan tanaman kelapa sawit menghasilkan, maka telah dilakukan percobaan penetapan laju respirasi harian kelapa sawit di lapangan. Pengamatan lapang dilakukan pada Maret 1996 – Maret 1997 di plot pengujian percobaan pemuliaan, No BJ 26 S, tahun tanam 1990, kebun Bah Jambi, PT Perkebunan Nusantara IV, Simalungun, Sumatera Utara (2°59' LU 99°13'). Pengamatan dibagi dalam tiga aspek yaitu fotosintesis, pertumbuhan tanaman dan iklim. Laju fotosintesis diukur in situ. Parameter fotosintesis dapat diturunkan dari hasil pengukuran laju fotosintesis daun tunggal, dan merupakan dasar dari perhitungan asimilasi karbon potensial harian oleh tajuk tanaman. Diperoleh nilai parameter potensial fotosintesis (α) adalah 0,013 mg CO_2 J^{-1} dan laju fotosintesis pada cahaya jenuh (Pmaks) adalah 1,09 mg CO_2 m^{-2} $detik^{-1}$. Nilai parameter fotosintesis tersebut merupakan parameter utama dalam menghitung produksi asimilat harian kelapa sawit. Hasil perhitungan menunjukkan produksi asimilat kelapa sawit dapat mencapai 3 – 4 kg CH_2O $pohon^{-1}$ $hari^{-1}$. Sedangkan produksi bahan kering aktual bervariasi antara 0,6 – 1,0 kg $pohon^{-1}$ $hari^{-1}$, atau mencapai 20,8 % dari produksi asimilat harian hasil fotosintesis. Sekitar 79,2 % asimilat lainnya (2,5 – 3,5 kg CH_2O $pohon^{-1}$ $hari^{-1}$) digunakan untuk respirasi pertumbuhan (17,4 %) dan respirasi perawatan (61,8 %).

Kata kunci : *Elaeis guineensis*, respirasi, laju fotosintesis, asimilat

PENDAHULUAN

Tingkat pencapaian produksi tanaman ditentukan oleh kondisi pertumbuhan tanaman. Secara umum pertumbuhan tanaman merupakan hasil keseimbangan antara perolehan asimilat hasil fotosintesis dengan kehilangan asimilat untuk respirasi (2).

Kelapa sawit yang merupakan tanaman tahunan tropika dan berperawakan relatif besar melakukan respirasi sangat intensif, sehingga sebagian besar perolehan asimilat hasil fotosintesis digunakan untuk proses tersebut. Menurut Van Kraalingen, Breure, dan Spitters (13), tanaman kelapa sawit dewasa menggunakan sebagian besar asimilat hasil fotosintesis untuk kegiatan respirasi, sehingga asimilat yang digunakan untuk pertumbuhan dan produksi kelapa sawit relatif kecil.

Menurut Mc Cree (9), tanaman melakukan aktivitas respirasi untuk dua tujuan, yaitu respirasi yang menghasilkan energi untuk pembentukan struktur jaringan tanaman dan respirasi yang menghasilkan energi untuk mempertahankan atau merawat struktur jaringan tanaman. Formulasi kedua bentuk respirasi tersebut dalam persamaan tunggal berikut:

$$R_{total} = aA + bW \quad \text{.........................(I)}$$

R_{total} : Respirasi total (kg CH_2O)
A : Asimilat hasil fotosintesis harian (kg CH_2O)
W : Bobot biomassa tanaman (kg)

Koefisien a dan b adalah koefisien respirasi pertumbuhan dan koefisien respirasi perawatan tanaman.

Untuk mendeterminasi laju respirasi tersebut, diperlukan suatu analisis keseimbangan asimilat (5), yang bentuknya:

$$dA = dA_g + dA_m \quad \text{(II)}$$

dA : Asimilat hasil fotosintesis (kg CH_2O $hari^{-1}$)
dA_g : Bagian asimilat untuk pertumbuhan (kg CH_2O $hari^{-1}$)
dA_m : Bagian asimilat perawatan (kg CH_2O $hari^{-1}$)

Bagian asimilat untuk pertumbuhan (dA_g), digunakan untuk penambahan masa tanaman (dW) dan respirasi pertumbuhan (dA_r)

$$dA_g = dW + dA_r \quad \text{(III)}$$

Apabila dA_r, dA_g, dan dA_m dapat diperoleh, maka laju respirasi total (R_{total}) dan koefisen respirasi perawatan (b) dapat dihitung sebagai berikut:

$$R_{total} = dA_r + dA_m \quad \text{(IV)}$$

$$b = dA_m / W \quad \text{(V)}$$

Secara praktis, laju respirasi perawatan dapat dideterminasi melalui persamaan berikut:

$$dA_m = b\,W\,Q_{10} \quad \text{(VI)}$$

Q_{10} : Kuosien suhu (tanpa satuan)

Penelitian ini bertujuan menerapkan metode analisis keseimbangan asimilat untuk menentukan laju respirasi kelapa sawit menghasilkan yang merupakan salah satu aspek yang diperhatikan dalam pemodelan pertumbuhan dan produksi tanaman kelapa sawit.

BAHAN DAN METODE

Penelitian lapangan dilakukan pada Maret 1996 – Maret 1997 di plot pengujian percobaan pemuliaan, No. BJ-26 S, tahun tanam 1990, kebun Bah Jambi, PT Perkebunan Nusantara IV, Simalungun, Sumatera Utara (2°59' LU 99°13'). Bahan tanaman yang digunakan adalah tanaman kelapa sawit yang sudah menghasilkan klon MK 60. Luas areal yang digunakan adalah sekitar 2000 m^2 yang merupakan bagian dari suatu blok pertanaman kelapa sawit (25 ha). Jumlah pohon yang digunakan dalam penelitian ini adalah 24 pohon dengan jarak tanam 9,4 m x 8,1 m (130 pohon ha^{-1}). Pengamatan dibagi dalam tiga aspek yaitu fotosintetis, pertumbuhan tanaman dan cuaca.

Laju fotosintesis diukur *in situ* pada berbagai kedudukan pelepah daun, yaitu yang terletak di tajuk bagian atas diwakili oleh pelepah ke-9, pelepah yang terletak di tajuk bagian tengah diwakili oleh pelepah ke-17, dan pelepah yang terletak di tajuk bagian bawah diwakili oleh pelepah ke-25, menggunakan analisis portabel (IRGA, tipe LCA-4 (Analytical Development Co., UK) mengikuti metode Caemmerer dan Farquhar (1). Dari hasil pengukuran laju fotosintesis daun tunggal tersebut kemudian diturunkan parameter fotosintesis menggunakan teknik analisis regresi. Parameter laju fotosintesis adalah parameter utama dalam menghitung asimilasi karbon potensial harian oleh tajuk tanaman berdasar metode SUCROS (8,12).

Pertumbuhan tanaman diukur nondestruktif (3), yang meliputi organ tanaman vegetatif dan generatif. Organ tanaman vegetatif meliputi pelepah daun, batang, dan akar. Pertumbuhan biomassa organ akar diukur secara tidak langsung dari produksi organ vegetatif lainnya (batang dan pelepah daun), yang diperkirakan sebesar 12 % dari keseluruhan produksi biomassa organ vegetatif (6,13). Organ generatif yang diamati adalah bunga betina mulai dari kuncup hingga menjadi buah matang panen. Sedangkan organ generatif bunga jantan diabaikan karena bobotnya relatif kecil (1 – 1,6 % dari produksi total, (4) dan umurnya relatif pendek. Produksi biomassa dikonversikan dalam satuan bobot CH_2O, yang dapat memberikan gambaran mengenai kebutuhan asimilat masing-masing organ. Hal ini lebih akurat dibanding dalam satuan bobot kering biomassa, karena memiliki satuan yang sama dengan perolehan biomassa hasil fotosintat. Sehingga lebih sesuai untuk analisis keseimbangan perolehan dan kehilangan asimilat.

Konversi bahan kering ke satuan asimilat (CH_2O) didasarkan pada komposisi biokimia penyusun masing-masing organ (karbohidrat, lipida, lignin, asam organik, protein, dan mineral). Berdasarkan rerata komposisi biokimia masing-masing organ dan efisiensi konversinya dalam satuan asimilat (Lampiran 1), maka diperoleh faktor konversi berturut-turut untuk organ daun, batang, akar, dan buah adalah 1,44; 1,52; 1,54; dan 2,31 (11, 6,4,13).

Unsur cuaca yang diamati adalah curah hujan (mm hari^{-1}) menggunakan alat ombrometer automatis, suhu udara (°C hari^{-1}) menggunakan alat termometer minimum-maksimum, lama penyinaran (jam hari^{-1}) menggunakan alat compbel stokes, kelembaban relatif udara (%) menggunakan alat psychrometer, dan kecepatan angin (km hari^{-1}) menggunakan alat anemometer pada ketinggian 2 m di atas permukaan laut.

Pengamatan unsur cuaca tersebut dilakukan di stasiun meteorologi pertanian Balai Penelitian Marihat, yang terletak sekitar 2,5 km dari lokasi penelitian.

HASIL DAN PEMBAHASAN

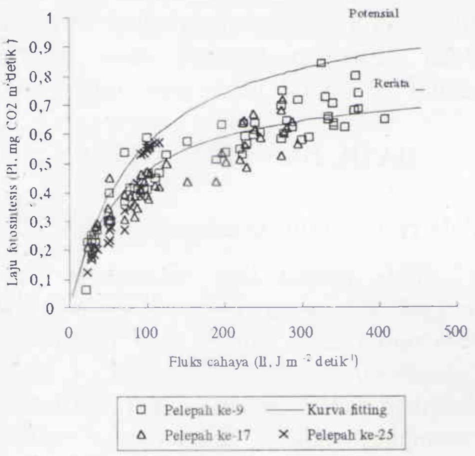
Pola respon laju fotosintesis

Pola respon laju fotosintesis daun tunggal kelapa sawit terhadap intensitas spektrum radiasi cahaya aktif fotosintesis (*photosynthetically active radiation*, PAR) disajikan pada Gambar 1. Laju fotosintesis meningkat tajam dengan peningkatan intensitas cahaya sampai pada 240 J m^{-2} detik^{-1}. Pada intensitas cahaya lebih besar dari 240 J m^{-2} detik^{-1}, laju fotosintesis cenderung konstan. Menurut Gerritsma, Goudriaan, dan Bink (7) dan Van Kraalingen *et al.* (13), laju fotosintesis pada kondisi intensitas cahaya lebih besar dari 240 J m^{-2} detik^{-1} merupakan laju fotosintesis cahaya jenuh (Pmaks). Nisbah laju fotosintesis terhadap penambahan intensitas cahaya pada intensitas cahaya rendah (kurang dari 30 J m^{-2} detik^{-1}) merupakan nilai efisiensi fotosintesis (α). Pmaks dan α adalah parameter fotosintesis yang menentukan pola respon tanaman dalam aktivitas fotosintesis terhadap intensitas cahaya, yang digambarkan oleh

France dan Thornley (5) dengan persamaan berikut:

Pl = (α Il Pmaks)/(α Il + Pmaks)....(VII)

Pl : Laju fotosintesis (kgCO_2 m^{-2} $detik^{-1}$)
α : Efisiensi fotosintesis (g CO2 J^{-1})
Il : Intensitas cahaya (J m^{-2} $detik^{-1}$)
P_{maks} : Laju fotosintesis pada fluks cahaya jenuh (kg CO_2 m-^{2} detik-^{1})



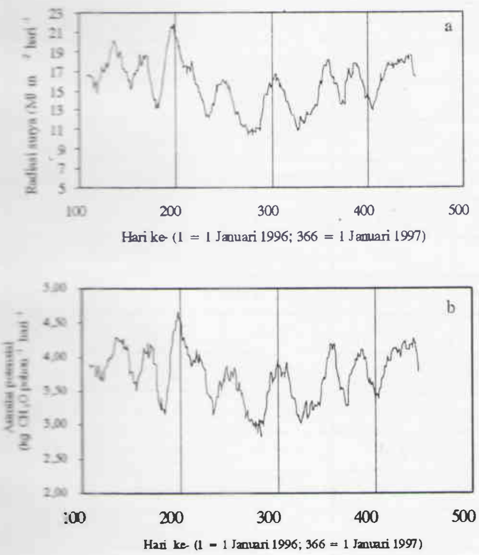
Gambar 1. Respon laju fotosintesis daun tunggal terhadap intensitas cahaya spektrum radiasi fotosintesis aktif

Penurunan parameter hasil pengukuran laju fotosintesis pada berbagai kedudukan pelepah daun, yang terletak di tajuk bagian atas diwakili oleh pelepah ke-9, pelepah di tajuk bagian tengah diwakili oleh pelepah ke-17, dan pelepah di tajuk bagian bawah diwakili oleh pelepah ke-25, dilakukan menggunakan teknik analisis regresi terhadap persamaan (VII). Dengan analisis regresi tersebut diperoleh nilai α dan P_{maks} masing-masing adalah 0,011 mg CO_2 J^{-1} dan 0,72 mg CO_2 m^{-2} $detik^{-1}$. Nilai parameter tersebut diturunkan dari hasil pengukuran rerata laju fotosintesis pada berbagai intensitas radiasi surya. Nilai tertinggi hasil pengukuran laju fotosintesis pada berbagai intensitas radiasi surya digunakan untuk menduga nilai parameter fotosintesis potensial. Nilai parameter potensial tersebut α dan P_{maks} adalah 0,013 mg CO_2 J^{-1} dan 1,09 mg CO_2 m^{-2} $detik^{-1}$. Kurva respon laju fotosintesis potensial terhadap intensitas cahaya lebih tinggi dibandingkan kurva respon laju fotosintesis aktual. Kurva ini gambaran laju fotosintesis maksimum yang dapat dicapai tanaman pada suatu lingkungan yang diasumsikan tidak memiliki faktor pembatas. Nilai parameter fotosintesis potensial tersebut digunakan sebagai parameter utama dalam memprediksi jumlah asimilat potensial yang dihasilkan kelapa sawit pada proses fotosintesis tajuk tanaman (8,12).

Asimilasi karbon potensial tajuk tanaman

Asimilasi karbon tajuk tanaman merupakan bentuk integrasi atau jumlah keseluruhan dari aktivitas fotosintesis daun tunggal. Metode penghitungan asimilat potensial harian pada kelapa sawit dikembangkan oleh Goudriaan dan Van Laar (8) dan Van Kraalingen *et al.* (13). Metode tersebut dikenal dengan nama SUCROS, yang memerlukan parameter fotosintesis daun tunggal. Dari hasil pengukuran fotosintesis daun tunggal (Gambar 1), diperoleh α 0,013 mg CO_2 J^{-1} yang setara dengan 0,46 kg CO_2 J^{-1} Jam^{-1} dan P_{maks} 1,09 mg CO_2 m^{-2} $detik^{-1}$ atau setara dengan 39 kg CO_2 ha^{-1} jam^{-1}.

Hasil penghitungan pada kondisi penutupan tajuk LAI 5 menunjukkan bahwa asimilat potensial harian bervariasi antara 2,8 – 4,7 kg CH_2O pohon^{-1} hari^{-1}. Variasi asimilat potensial ditentukan oleh jumlah radiasi yang diterima, sehingga pola fluktuasinya identik dengan radiasi surya (Gambar 2). Penghitungan asimilat potensial merupakan gambaran kapasitas fotosintesis harian. Nisbah fotosintesis harian terhadap produksi bahan kering harian menunjukkan jumlah bagian asimilat yang digunakan dalam respirasi tanaman.



Gambar 2. Fluktuasi harian (a) radiasi surya, dan (b) asimilat

Produksi bahan kering harian

Produksi bahan kering harian dalam satuan asimilat bervariasi antara 1 – 2 kg CH_2O pohon^{-1} hari^{-1}. Produksi bahan kering tersebut bervariasi terhadap radiasi surya dan ketersediaan air tanah. Produksi bahan kering yang tinggi dapat dicapai apabila ketersediaan air dan radiasi surya tidak merupakan faktor pembatas (Gambar 3). Produksi bahan kering relatif kecil apabila salah satu atau kedua faktor tersebut dalam keadaan terbatas. Produksi bahan kering relatif tinggi terjadi pada nomor hari 170 – 180 (21 – 27 Juni 1996), sebab radiasi surya maupun ketersediaan airnya dalam kondisi optimum. Sebaliknya produksi bahan kering yang rendah pada hari ke- 350 – 360 (15 – 25 Desember 1996) disebabkan faktor ketersediaan air yang terbatas. Sedangkan pada hari ke- 260 – 270 (16 – 26 September 1996), produksi bahan kering rendah disebabkan oleh radiasi surya rendah yang diterima tanaman walaupun ketersediaan air memadai.

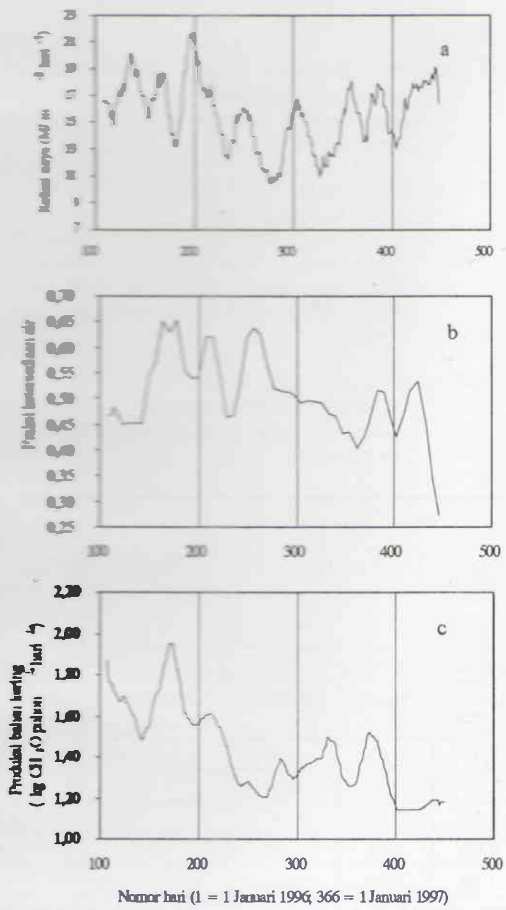
Respirasi

Hasil perhitungan keseimbangan asimilat (Tabel 1) menunjukkan bahwa laju respirasi total harian (R_{total}) berkisar antara 2,50 – 3,50 kg CH_2O pohon^{-1} hari^{-1} atau setara dengan emisi 2,75 – 3,85 kg CO_2 pohon^{-1} hari^{-1}. Laju respirasi tersebut menggunakan sekitar 79,2 % perolehan asimilat hasil fotosintesis, yang jumlah reratanya 3,67 kg CH_2O pohon^{-1} hari^{-1}. Setiap pohon kelapa sawit menggunakan sekitar 0,64 kg CH_2O hari^{-1} atau sekitar 17,4 % hasil fotosintesis untuk respirasi pertumbuhan dan sekitar 2,27 kg CH_2O hari^{-1} atau sekitar 61,8 % hasil fotosintesis untuk respirasi perawatan.

Berdasarkan hasil perhitungan di atas, proses respirasi perawatan menggunakan asimilat yang relatif besar dibandingkan dengan tanaman setahun. Hal tersebut berhubungan dengan keragaan kelapa sawit yang relatif besar (tanaman tahunan), sehingga energi yang diperlukan untuk mempertahankan struktur tubuhnya menjadi besar. Nisbah antara bagian asimilat untuk respirasi perawätan dengan bobot tanaman dikenal sebagai koefisien respirasi perawatan (persamaan 1). Nilai rerata koefisien respirasi perawatan (b) tersebut adalah 0,0053 kg CH_2O kg^{-1} bahan kering. Nilai tersebut dihitung pada suhu rerata harian 24,53°C (Tabel 1). MC Cree (9,10) menyatakan bahwa laju respirasi bervariasi terhadap suhu, sehingga nilai koefisien respirasi perawatan tersebut harus dikoreksi terhadap suhu udara dengan suatu faktor kuosien suhu (Q_{10}).

Tabel 1. Hasil penghitungan komponen-komponen keseimbangan asimilat

No hari	Asimilat potensial (dA, kg CH_2O $pohon^{-1}$ $hari^{-1}$)	Produksi bahan kering (dW, kg $pohon^{-1}$ $hari^{-1}$)	Respirasi pertumbuhan (dA_g, kg CH_2O $pohon^{-1}$ $hari^{-1}$)	Respirasi perawatan (dA_r, kg CH_2O $pohon^{-1}$ $hari^{-1}$)	Respirasi total (R_{total}, kg CH_2O $pohon^{-1}$ $hari^{-1}$)	Bobot kering tanaman (W, kg $pohon^{-1}$)	Koefisien respirasi perawatan (b, kg CH_2O kg bobot kering $hari^{-1}$)	Suhu udara (°C)
110	3,87	0,99	0,83	2,05	2,88	372,10	0,0055	24,50
130	3,77	0,92	0,77	2,08	2,85	372,10	0,0056	25,15
150	3,82	0,80	0,67	2,35	3,02	387,35	0,0061	25,00
165	3,82	0,92	0,77	2,13	2,90	387,35	0,0055	24,95
178	4,17	1,08	0,90	2,19	3,09	390,41	0,0056	25,30
193	3,89	0,85	0,71	2,33	3,04	399,62	0,0058	24,65
208	3,89	0,85	0,71	2,33	3,04	399,62	0,0058	24,95
222	3,93	0,86	0,73	2,34	3,07	412,48	0,0057	24,60
229	3,46	0,82	0,68	1,96	2,64	417,55	0,0047	24,90
250	3,61	0,69	0,58	2,34	2,92	421,55	0,0056	24,50
264	3,33	0,66	0,56	2,11	2,67	422,71	0,0050	24,20
271	3,33	0,65	0,55	2,13	2,68	422,71	0,0050	24,05
278	3,33	0,65	0,55	2,13	2,68	422,71	0,0050	23,80
298	3,76	0,69	0,58	2,49	3,07	431,02	0,0058	24,90
305	3,76	0,73	0,61	2,42	3,03	431,02	0,0056	23,60
312	3,68	0,73	0,61	2,34	2,95	435,25	0,0054	23,85
326	3,12	0,74	0,62	1,76	2,38	440,15	0,0040	25,10
334	3,12	0,77	0,64	1,72	2,36	440,15	0,0039	24,55
347	3,48	0,73	0,62	2,13	2,75	450,81	0,0047	23,80
354	3,48	0,68	0,58	2,23	2,81	464,08	0,0048	23,85
369	3,65	0,69	0,58	2,38	2,96	464,08	0,0051	24,45
396	3,80	0,71	0,60	2,50	3,10	495,20	0,0050	25,25
403	3,80	0,62	0,52	2,66	3,18	495,20	0,0054	23,50
425	3,80	0,62	0,52	2,66	3,18	495,20	0,0054	24,95
439	4,13	0,64	0,54	2,94	3,48	519,20	0,0057	24,85
Rerata	3,67	0,76	0,64	2,27	2,91	431,6	0,0053	24,53



Gambar 3. Fluktuasi harian (a) radiasi surya, (b) ketersediaan air, dan (c) produksi bahan kering

KESIMPULAN

Berdasarkan hasil pengukuran laju fotosintesis daun tunggal kelapa sawit diperoleh nilai parameter potensial fotosintesis (α) sebesar 0,013 mg CO_2 J^{-1} dan laju fotosintesis pada cahaya jenuh (P_{maks}) adalah 1,09 mg CO_2 m^{-2} $detik^{-1}$. Parameter potensial laju fotosintesis tersebut merupakan parameter utama dalam menghitung produksi asimilat harian kelapa sawit. Berdasarkan perhitungan tersebut diketahui bahwa produksi asimilat kelapa sawit dapat mencapai 3 – 4 kg CH_2O $pohon^{-1}$ $hari^{-1}$, sedangkan produksi bahan kering aktual bervariasi antara 0,6 – 1,0 kg $pohon^{-1}$ $hari^{-1}$, atau mencapai 20,8 % dari produksi asimilat harian hasil fotosintesis. Sekitar 79,2 % asimilat lainnya (2,5 – 3,5 kg CH_2O $pohon^{-1}$ $hari^{-1}$) digunakan untuk respirasi pertumbuhan (17,4 %) dan respirasi perawatan (61,8).

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Lampiran 1. Komposisi biokimia tiap organ tanaman dan kesetaraannya terhadap asimilat (4,6,11,dan 13)

	Komposisi biokimia dalam persen bobot kering						
Organ	Karbohidrat	Lipida	Lignin	Asam organik	Protein	Mineral	Kebutuhan kg CH_2O kg^{-1} bahan kering *)
Daun	0,75	0,05	0,05	0,05	0,06	0,04	1,44
Batang	0,02	0,20	0,20	0,02	0,04	0,04	1,52
Akar	0,02	0,20	0,20	0,02	0,03	0,02	1,54
Tandan buah	0,48	0,04	0,04	0,02	0,03	0,02	2,31
Kesetaraan CH_2O	1,32	3,33	2,27	0,98	2,00	0,10	

*) misal kebutuhan asimilat (faktor konversi) untuk daun dihitung sebagai 0,75 x 1,32 + 0,05 x 3,33 + 0,05 x 2,27 + 0,05 x 0,98 + 0,06 x 2,00 + 0,04 x 0,01 = 1,44 kg CH_2O kg^{-1} bahan kering

Calculation of oil palm (*Elaeis guineensis* Jacq) respiration rate based on assimilate balancing analysis

Iman Yani Harahap, Subronto, and Witjaksana Darmosakoro

Abstract

To know the role of respiration in growth process of mature oil palm, the trial for determining daily respiration rate in the field was done. Field observations were undertaken in March 1996 until March 1997 in the breeding trial plot, No. BJ-26-S, using oil palm trees planted in 1990 at Bah Jambi estate, PTPN IV, Simalungun, North Sumatera (2° 59'N, 99°13'E). The observations were conducted in three separated aspects; they were photosynthesis, plant growth, and climate. Rate of photosynthesis was measured in situ. The photosynthetic parameters can be derived from the measurement on a single leaf and it was base on the calculation of daily potential canopy carbon assimilation. From result of photosynthesis measurement on single leaf, potential photosynthetic parameters were derived, that were efficiency of photosynthesis (α) 0.013 mg CO_2 J^{-1} and rate of photosynthesis on light saturated (P_{maks}) 1.09 mg CO_2 m^{-2} s^{-1}. The values were the main parameters in calculation of daily assimilate production. Result of the calculation showed that the assimilate production of oil palm can reach 3 – 4 kg CH_2O $tree^{-1}$ day^{-1}. Whereas, actual production of dry matter varied between 0.6 – 1.0 kg $tree^{-1}$ day^{-1}, which means that the dry matter production was around 20.8 % of daily assimilate production. Other portion of assimilates (79.2 %; 2.5 – 3.5 kg CH_2O $tree^{-1}$ day^{-1}) was used for growth respiration and maintenance respiration at 17.4 % and 61.8 %, respectively.

Keywords : *Elaeis guineensis*, respiration , rate of photosynthesis, assimilate

Introduction

Crop yield was determined by the growth condition. Generally, crop growth is a result of the balance of assimilates between production from photosynthetic process and the lost for respiration (2).

Oil palm, a tropical perennial crop with relatively big posture, respires intensively, so that most assimilates resulted from photosynthesis is used for the process. According to Van Kraalingan, Breure, and Spitters (13), most assimilates resulted from photosynthetic process of adult oil palm were used for respiration activity, hence the assimilates used for growth and yield of oil palm are relatively small.

According to Mc Cree (9), plant respiration activity has two purposes, they are respiration to produce energy for plant body structure formation, and respiration to maintain plant body structure. Both respiration activities could be formulated into a single equation:

$$R_{total} = aA + bW \qquad \text{(I)}$$

R_{total} : Total respiration (kg CH_2O)
A : Assimilate from daily photosynthesis (kg CH_2O)
W : Plant biomass weight (kg)

Coefficient a and b were growth and maintenance respiration coefficient, respectively.

To determine respiration rate, the analysis of assimilate balance was used (5), which can be expressed in the following equation:

$dA = dA_g + dA_m$ ....(II)

dA : Assimilate from daily photosynthesis (kg day^{-1} CH_2O)
dA_g : Assimilate for growth (kg day^{-1} CH_2O)
dA_m : Assimilate for maintenance (kg day^{-1} CH_2O)

Assimilate for growth (dA_g), is used for plant biomass increment (dW) and growth respiration (dA_r)

$dA_g = dW + dA_r$..........................(III)

If dA_r, dA_g, and dA_m can be obtained, then the respiration rate (R_{total}) and maintenance respiration coefficient (b) can be calculated, as follow :

$R = dA_r + dA_m$ .... (IV)

$B = dA_m /W$ ....(V)

Finally, maintenance respiration rate will be practically determined with following equation:

$dA_m = b\ W\ Q_{10}$.......(VI)

Q_{10} : Temperature Quotion

The objective of this study is to apply method of assimilate balancing analysis for determining respiration rate of mature oil palm.

Materials and Methods

Field research was conducted in March 1996 – March 1997, at Indonesian Oil Palm Research Institute (IOPRI) breeding trial plot, No. BJ-26-S, planted in 1990, at Bah Jambi estate, PTPN IV, Simalungun, North Sumatera (2°59' N - 99°13'). Plant materials used were adult oil palms of clone MK 60. The area used was around 2000 m^2 that was part of oil palm planting area (around 25 ha). Total oil palm used was 24 palms with planting space of 9.4 m x 8.1 m (130 palms ha^{-1}). The observation were conducted for three separated aspects, they were photosynthetic aspect, growth, and climate condition.

Photosynthetic rate was measured in situ on several leaf frond position (frond no. 9 represents the top of canopy; frond no. 17 represents the middle of canopy; and frond no. 25 represents the below of canopy) using portable analyzer (IRGA), type LCA-4 (Analytical Development Co., UK) referring to Caemmer and Farquhar method (1). Photosynthetic parameters can be derived from the result of the single photosynthetic measurement. The photosynthetic parameters are the main input in calculating plant daily carbon assimilation by using SUCROS method (8,12).

Non-destructive plant growth measurement was done referring to Corley Hardon, and Tan (3), included vegetative and generative organs. Vegetative organs included leave, stem, and root. Non-direct measurement was done on root biomass. The root was predicted through the other organs (leave and stem), which was 12 % of vegetative biomass production (6,13). The generative organ observation was done on the growth of female flower starting from bud till fruit bunch ripen. Male flower was ignored because the biomass was relatively small (1 – 6 % of total production) (4) with short lifetime. The conversion was also more compatible to analyze the balance of the gained and the lost assimilates.

The conversion was based on the biochemical content and composition of the organ (i.e., carbohydrate, lipid, lignin, organic acid, protein, and minerals). Conversion values of 1.44; 1.52; 1.54; and 2.31 were taken for leaf, stem, root, and fruit bunch, respectively (11, 6, 4, 13) (Appendix 1).

Climate aspects were observed, which were including rainfall (mm day^{-1}) using automatically ombrometer, daily air temperature (°C day^{-1}) using minimum-maximum thermometer, sunshine duration (hour day^{-1}) using compbel stokes, relative humidity (%) using psychrometer, and wind speed (km day^{-1}) using anemometer at 2 m above ground level. The climate observation was undertaken at the station of agro-meteorology in Marihat Research Station (about 2.5 km from the trial location).

Results and Discussion

Pattern of photosynthetic rate response

Single leaf photosynthetic rate of oil palm at various intensity of photosynthetically active radiation (PAR) is showed in Figure 1. Rate of photosynthesis increased sharply with light intensity increment until 240 J m^{-2} s^{-1}, then the rate of photosynthesis tended to be constant. According to Gerritsma, Goudriaan, and Bink (7) and Van Kraalingen *et al.* (13), photosynthetic rate at above 240 J m^{-2} s^{-1} is light saturated photosynthesis (P_{maks}). Ratio of the change of photosynthetic rate to the increasing of light intensity at low light intensity (under 30 J m^{-2} s^{-1}) was the value of photosynthetic efficiency (α). P_{maks} and α are photosynthetic parameters determining the pattern of photosynthetic rate response on light intensity. The equation was described by France and Thornley (5) as follow:

$$Pl = (\alpha\ Il\ P_{maks})/(\alpha\ Il + P_{maks}) \ldots\ldots\ldots\ldots (VII)$$

Pl : Rate of photosynthesis (kg CO_2 m^{-2} s^{-1})
α : Photosynthetic efficiency (g CO_2 J^{-1})
Il : Light intensity (J m^{-2} s^{-1})
P_{maks} : Light saturated photosynthetic rate (kg CO_2 m^{-2} s^{-1})

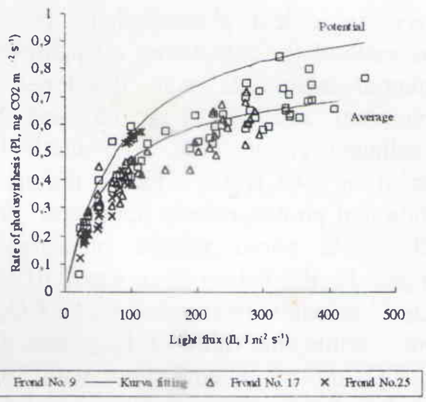

Figure 1. Response of single leaf photosynthetic rate on light intensity

Parameter derivation was done using regression analysis technique on equation VII. Results of calculation indicated that α and P_{maks} were 0,011 mg CO_2 J^{-1} and 0,72 mg CO_2 m^{-2} s^{-1}, respectively. The values were derived from result of average measurement of photosynthetic rate at several light intensity condition. The highest value of measurement was used to predict the potential photosynthesis. Potential photosynthetic parameters were 0,013 mg CO_2 J^{-1} and 1,09 mg CO_2 m^{-2} s^{-1} for α and P_{maks}, respectively. The potential photosynthetic rate on light intensity was higher than the actual photosynthetic rate. The phenomena reflected that the maximum photosynthetic rate can be obtained on an environment without limiting factors. Values of potential photosynthetic parameter were the main parameters to predict potential assimilate in crop photosynthetic process (8,12).

Crop potential carbon assimilation

Crop carbon assimilation is the total amount of carbon assimilation produced in every single leaf photosynthetic process. The method for calculating oil palm daily potential assimilate was developed by Goudriaan and Van Laar (8) and Van Kraalingen *et al.* (13). The method is known as SUCROS, which requires a single leaf photosynthetic parameter. From leaf single photosynthetic measurement (Figure 1), the values of α was 0.013 mg CO_2 J^{-1} or equivalent with 0.46 kg CO_2 J^{-1} $hour^{-1}$, while the value of P_{maks} was 1.09 mg CO_2 m^{-2} s^{-1} or equivalent with 39 kg CO_2 ha^{-1} $hour^{-1}$. The calculation at LAI 5 showed that the daily potential assimilate were around 2.8 – 4.7 kg CH_2O $tree^{-1}$ day^{-1}. Variation of the potential assimilate was driven by solar radiation intercepted by crop, so that the assimilate production pattern followed the solar radiation intensity (Figure 2). The daily potential assimilate describes daily photosynthetic capacity. Ratio of the daily photosynthesis to the dry matter production shows the amount of assimilates used in crop respiration.

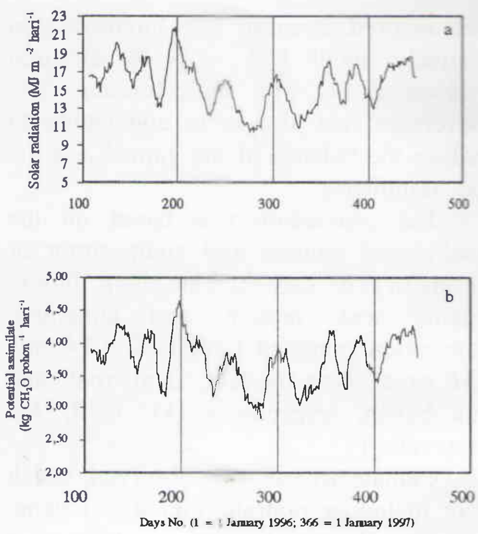

Figure 2. Daily fluctuation of (a) solar radiation, and (b) assimilate

Daily dry matter production

Daily production of dry matter in assimilate unit was about 1 – 2 kg CH_2O $tree^{-1}$ day^{-1}. The production depended upon the variation of solar radiation and soil water availability. High dry matter production was occurred when solar radiation and soil water availability did not become limiting factors (Figure 3). The production was relatively small, when one or both factors were in limited condition. The high production occurred in the days 170 – 180 (21 – 27 June 1996), where solar radiation and water availability were in optimum condition. On the contrary, the low production was occurred in the days 350-360 (15 – 25 December 1996) when the water availability was in limited condition. Within the days 260 – 270 (16 – 26 September 1996), the low production was caused by low solar radiation, although the water did not become limiting factor.

Respiration

The result of assimilate balance calculation showed that the daily total respiration rate (R_{total}) was around 2.50 – 3.50 kg CH_2O tree^{-1} day^{-1} or equivalent with emission of 2.75 – 3.85 kg CO_2 tree^{-1} day^{-1} (Table 1). The respiration activity used around 79.2 % of assimilates from photosynthesis, which was equal to around 3.67 kg CH_2O tree^{-1} day^{-1}. Each plant used around 0.64 kg CH_2O day^{-1} (17,4 %) of assimilates from photosynthesis for growth respiration and around 2,27 kg CH_2O day^{-1} (61,8 %) for maintenance respiration.

Table 1. Calculation result of assimilate balancing components

No. of days	Potential assimilate (dA, kg CH_2O tree^{-1} day^{-1})	Dry matter production (dW, kg tree^{-1} day^{-1})	Growth respiration (dA_g, kg CH_2O tree^{-1} day^{-1})	Maintenance respiration (dA_r, kg CH_2O tree^{-1} day^{-1})	Total respiration (R_{total}, kg CH_2O tree^{-1} day^{-1})	Weight of biomass plant (W, kg tree^{-1})	Coefficient of maintenance respiration (b, kg CH_2O kg dry matter day^{-1})	Air temperature (°C)
[illegible]	[illegible]	[illegible]	0.83	2.05	2.88	372.1	0.0055	24.5
[illegible]	3.77	[illegible]	0.77	2.08	2.85	372.1	0.0056	25.15
[illegible]	[illegible]	[illegible]	0.67	2.35	3.02	387.35	0.0061	25.0
[illegible]	[illegible]	[illegible]	0.77	2.13	2.90	387.35	0.0055	24.95
[illegible]	4.17	1.08	0.90	2.19	3.09	390.41	0.0056	25.30
[illegible]	[illegible]	[illegible]	0.71	2.33	3.04	399.62	0.0058	24.65
[illegible]	[illegible]	[illegible]	0.71	2.33	3.04	399.62	0.0058	24.95
[illegible]	[illegible]	[illegible]	0.73	2.34	3.07	412.48	0.0057	24.60
[illegible]	[illegible]	[illegible]	0.68	1.96	2.64	417.55	0.0047	24.90
[illegible]	[illegible]	[illegible]	0.58	2.34	2.92	421.55	0.0056	24.50
[illegible]	[illegible]	[illegible]	0.56	2.11	2.67	422.71	0.0050	24.20
[illegible]	[illegible]	[illegible]	0.55	2.13	2.68	422.71	0.0050	24.05
[illegible]	[illegible]	[illegible]	0.55	2.13	2.68	422.71	0.0050	23.80
[illegible]	[illegible]	[illegible]	0.58	2.49	3.07	431.02	0.0058	24.90
[illegible]	[illegible]	[illegible]	0.61	2.42	3.03	431.02	0.0056	23.60
[illegible]	[illegible]	[illegible]	0.61	2.34	2.95	435.25	0.0054	23.85
[illegible]	[illegible]	[illegible]	0.62	1.76	2.38	440.15	0.0040	25.10
[illegible]	[illegible]	[illegible]	0.64	1.72	2.36	440.15	0.0039	24.55
[illegible]	[illegible]	[illegible]	0.62	2.13	2.75	450.81	0.0047	23.80
[illegible]	[illegible]	[illegible]	0.58	2.23	2.81	464.08	0.0048	23.85
[illegible]	[illegible]	[illegible]	0.58	2.38	2.96	464.08	0.0051	24.45
[illegible]	[illegible]	[illegible]	0.60	2.50	3.10	495.20	0.0050	25.25
[illegible]	[illegible]	[illegible]	0.52	2.66	3.18	495.20	0.0054	23.50
[illegible]	[illegible]	[illegible]	0.52	2.66	3.18	495.20	0.0054	24.95
[illegible]	[illegible]	[illegible]	0.54	2.94	3.48	519.20	0.0057	24.85
Mean	[illegible]	[illegible]	0.64	2.27	2.91	431.6	0.0053	24.53

The calculation of assimilate partition showed that maintenance respiration process used a relatively great portion of assimilate. This condition may be related to the big oil palm posture (perennial plant), therefore required high energy for keeping the structure of plant body. Ratio of part of the assimilates used in maintenance respiration to plant biomass is known as maintenance respiration coefficient, which is defined in equation I. The average value of this coefficient was 0.0053 kg CH_2O kg^{-1} dry matter at 24.53°C of daily air temperature (Table 1). According to MC Cree (9,10), the rate of respiration is affected by temperature so that the value of the coefficient of maintenance respiration should be corrected with a factor known as quotion of temperature (Q_{10}).

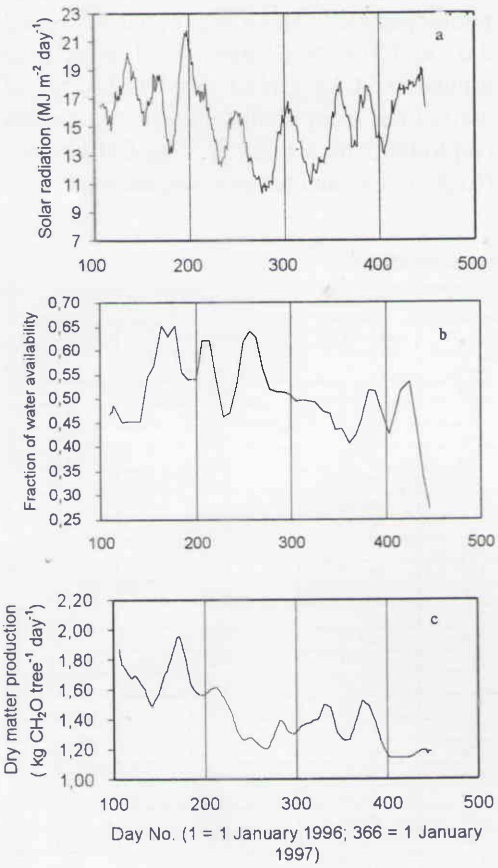

Figure 3. Daily fluctuation of (a) solar radiation, (b) water availability, and (c) dry matter production

Conclusion

Potential photosynthetic parameters derived from the measurement of single leaf photosynthetic rates of oil pam were 0.013 mg CO_2 J^{-1} for efficiency of photosynthesis (α) and 1.09 mg CO_2 m^{-2} s^{-1} for rate of photosynthesis on saturated light (P_{maks}). The values were the main parameters in the calculation of daily assimilate production. Result of the calculation showed that the assimilate production of oil palm can reach 3 – 4 kg CH_2O $tree^{-1}$ day^{-1}. Dry matter actual production varied between 0.6 – 1.0 kg $tree^{-1}$ day^{-1}, which means that the dry matter production was around 20.8 % of the daily assimilate production. Other portion of assimilates (79.2 %; 2.5 – 3.5 kg CH_2O $tree^{-1}$ day^{-1}) was used for growth respiration and maintenance respiration at 17,4 % and 61,8 %, respectively.

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Appendix 1. Biochemical composition of each organ and its equivalent to assimilate (4,6,11, and 13)

	Biochemical composition in percentage of dry matter						
Organs	Carbohydrate	Lipid	Lignin	Organic acid	Protein	Mineral	Requiring of kg CH_2O kg^{-1} dry matter *)
Leave	0.75	0.05	0.05	0.05	0.06	0.04	1.44
Stem	0.02	0.20	0.20	0.02	0.04	0.04	1.52
Root	0.02	0.20	0.20	0.02	0.03	0.02	1.54
Fruit bunch	0.48	0.04	0.04	0.02	0.03	0.02	2.31
CH_2O equivalent	1.32	3.33	2.27	0.98	2.00	0.10	

*) **Example.** Asimilate requiring (convertion factors) for leaves was calclulated as 0.75 x 1.32 + 0.05 x 3.33 + 0.05 x 2.27 + 0.05 x 0.98 + 0.06 x 2.00 + 0.04 x 0.01 = 1.44 kg CH_2O kg^{-1} dry matter