Introducing
_Tr、Ps、Pn_Simulator_

MATLAB™ BASED SOFTWARE RELATED TO EVAPOTRANSPIRATION & PHOTOSYNTHETIC RATE

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MATLAB™ BASED 軟體簡介

TrSimulator.m：蒸散速率 (Tr)

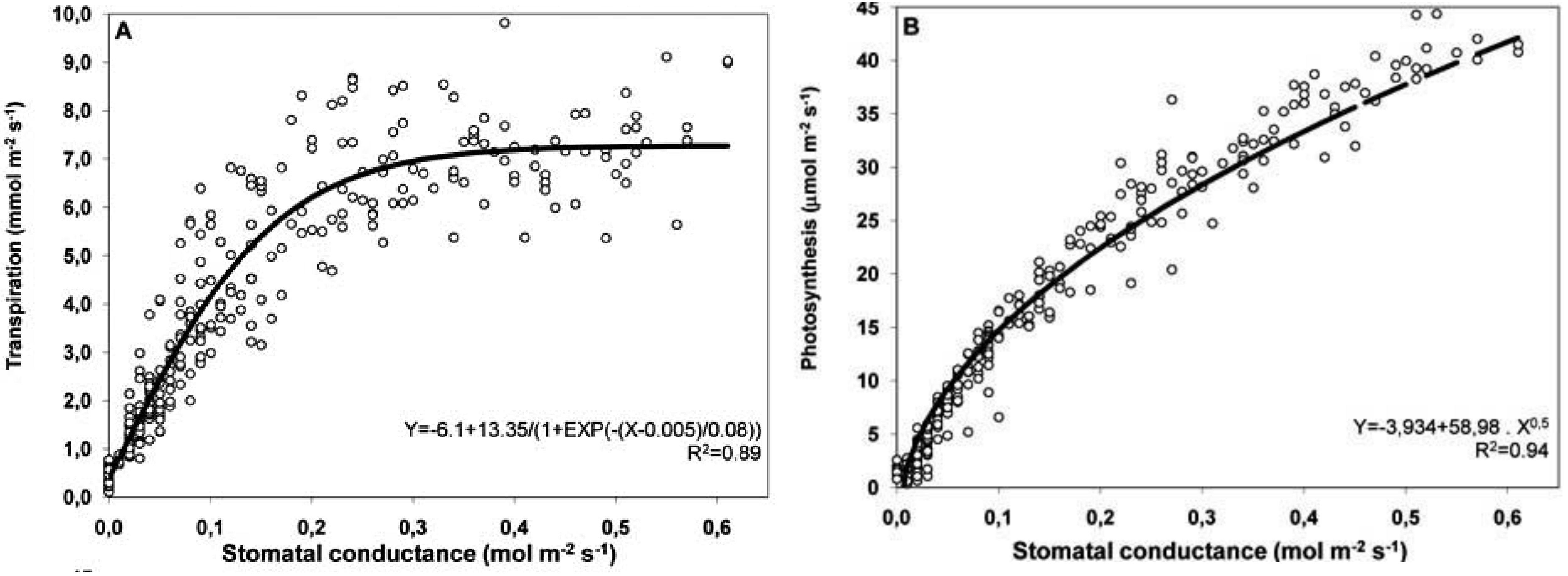
- 先算氣孔內外蒸汽壓差(VPD)與蒸氣密度差(VDD)
- 其次算水分離開氣孔的阻力 (Rv)，蒸散速率 (Tr = VDD / Rv)

PsSimulator.m：光合作用速率 (Ps)

- 先算 氣孔內外CO2 濃度差 dCO2
- 其次算二氧化碳進入氣孔的阻力 (Rc)，光合速率 (Ps = dCO2 / Rc)

PnSimulator.m：淨光合作用速率(Pn)

- 先算 Tr，再算 Ps
- 再其次計算暗呼吸 (Rd) 與光呼吸速率 (Rp)
- 最終計算淨光合速率 (Pn) 與 蒸散效率 (TE = Pn / Tr)



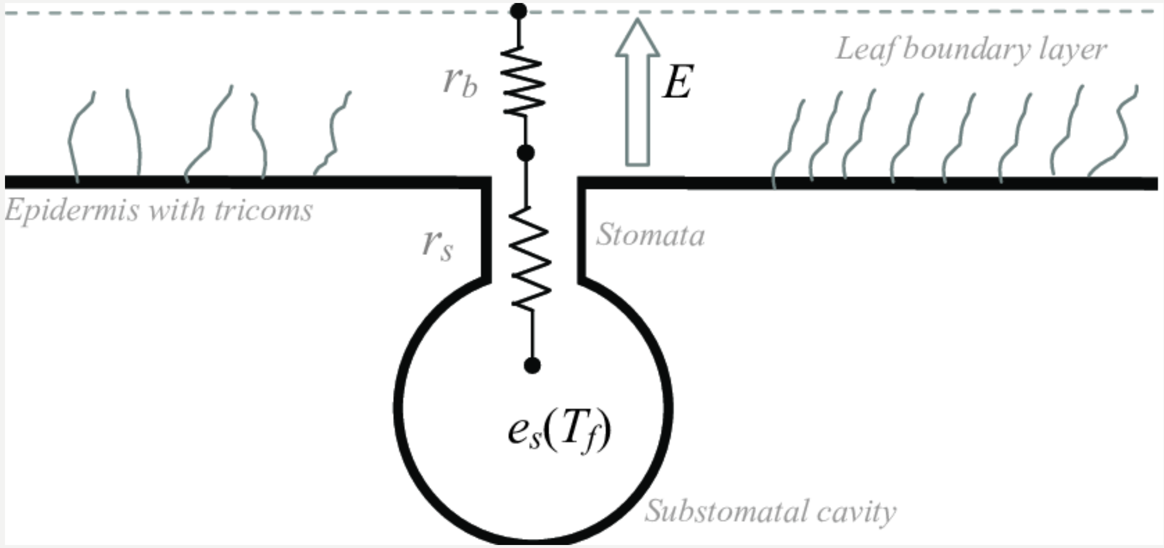
Relationship between stomatal conductance (A), transpiration (B), and photosynthesis in 28 sugarcane genotypes, n=360.

TrSimulator.m

蒸散速率的計算

$$T_r = \frac{VD_l - VD_a}{R_v}$$

Tr: Transpiration rate, $mg.m^{-2}.s^{-1}$
VD_l: Water vapor density in the stomata, mg m^{-3}
VD_a: Water vapor density in the air, mg m^{-3}
Rv: Total resistance, s/m



Rv = Rav + (Rlv + Rlv.inc)

Rav: Aerodynamic resistance, s/m (右圖的 r_b)
Rlv: Stomata resistance changed by irradiation, s/m (右圖的 r_s)
Rlv.inc: Increment of r_s based on CO2 concentration, s/m
下標 *l* 代表葉片，v 代表水汽，a 代表空氣

影響蒸散的因素

溫度、濕度影響 VPD、VDD、AHD

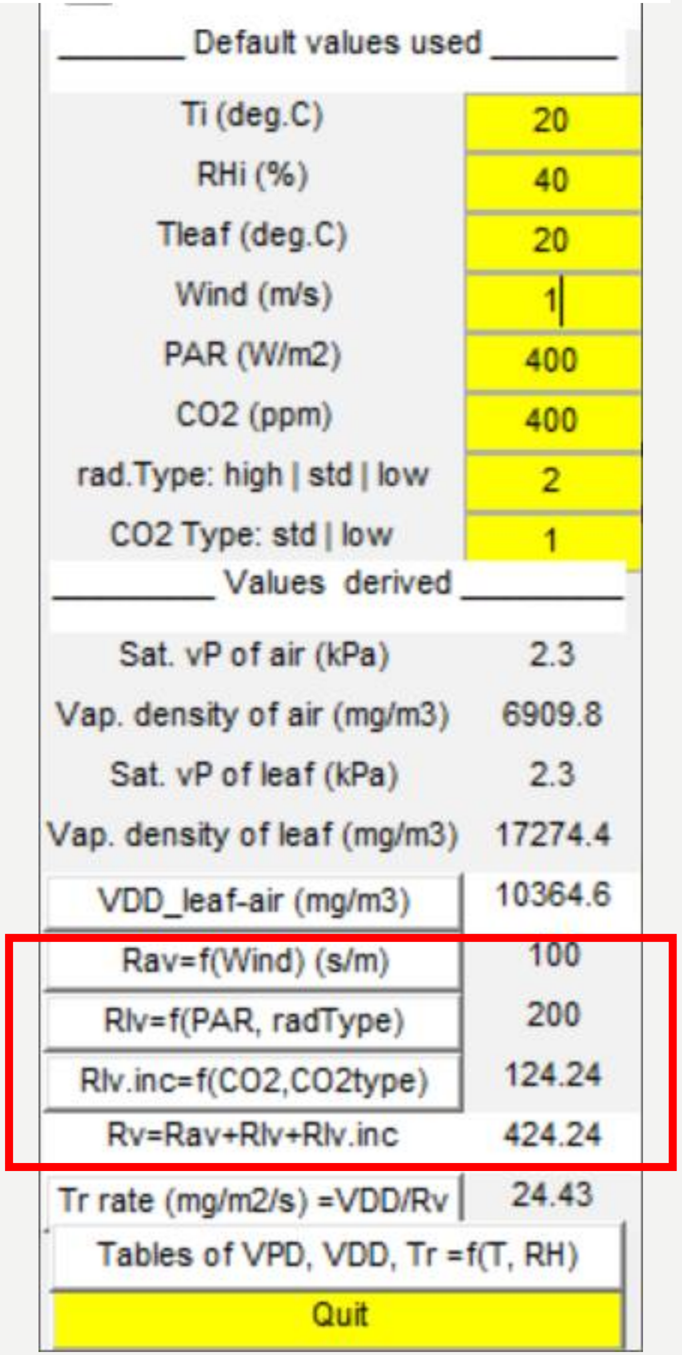
風速影響邊界層阻力：R_{av}

影響氣孔行為 (依作物別有不同程度的影響)

- 輻射量影響氣孔阻力：R_{lv}
- CO_2濃度影響氣孔阻力：$R_{lv.inc}$
- 其他尚未被量化的因素
  - 表皮細胞含水量、礦物質

$$R_v = R_{av} + R_{lv} + R_{lv.inc}$$

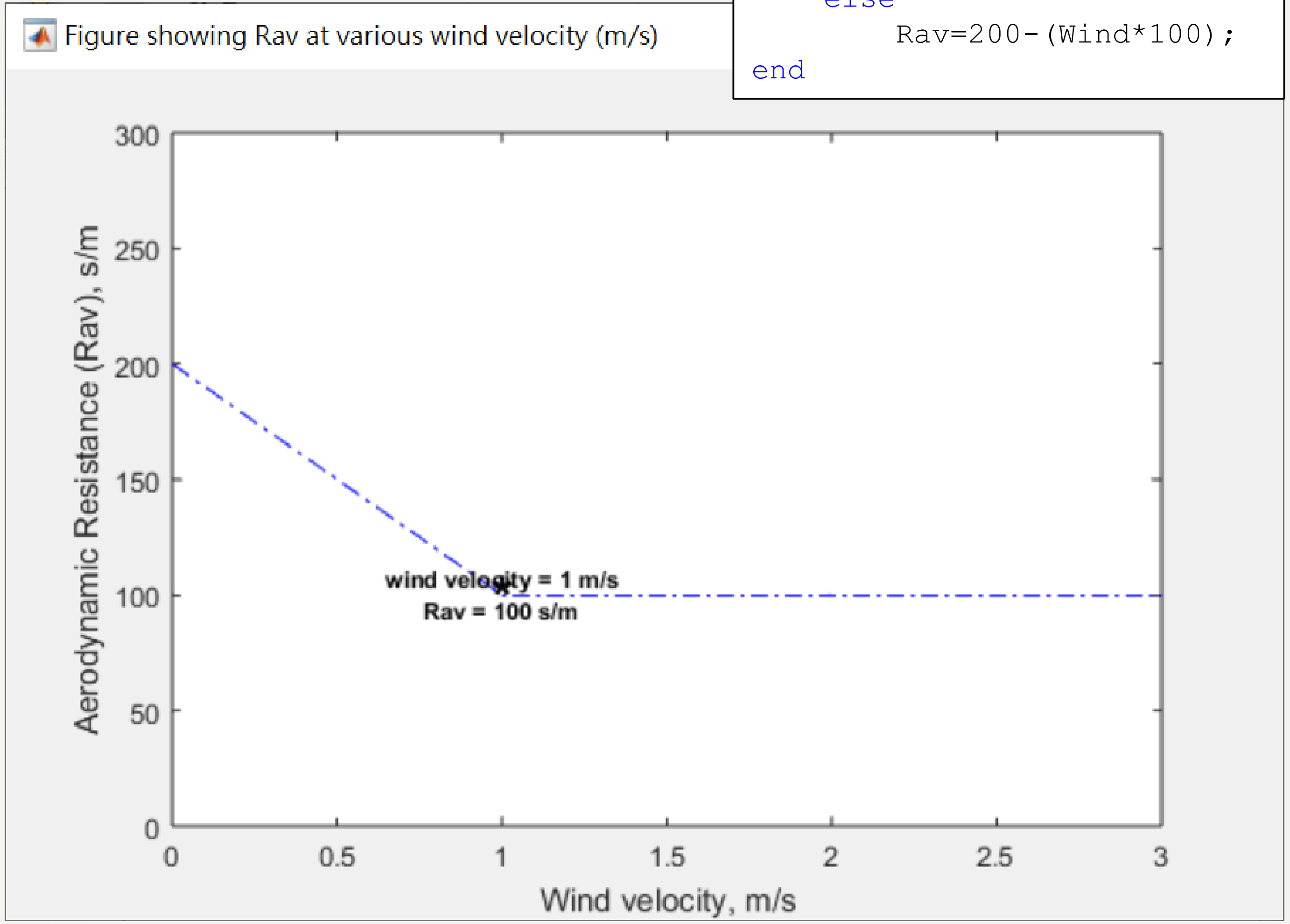
TrSimulator 的參數編輯視窗

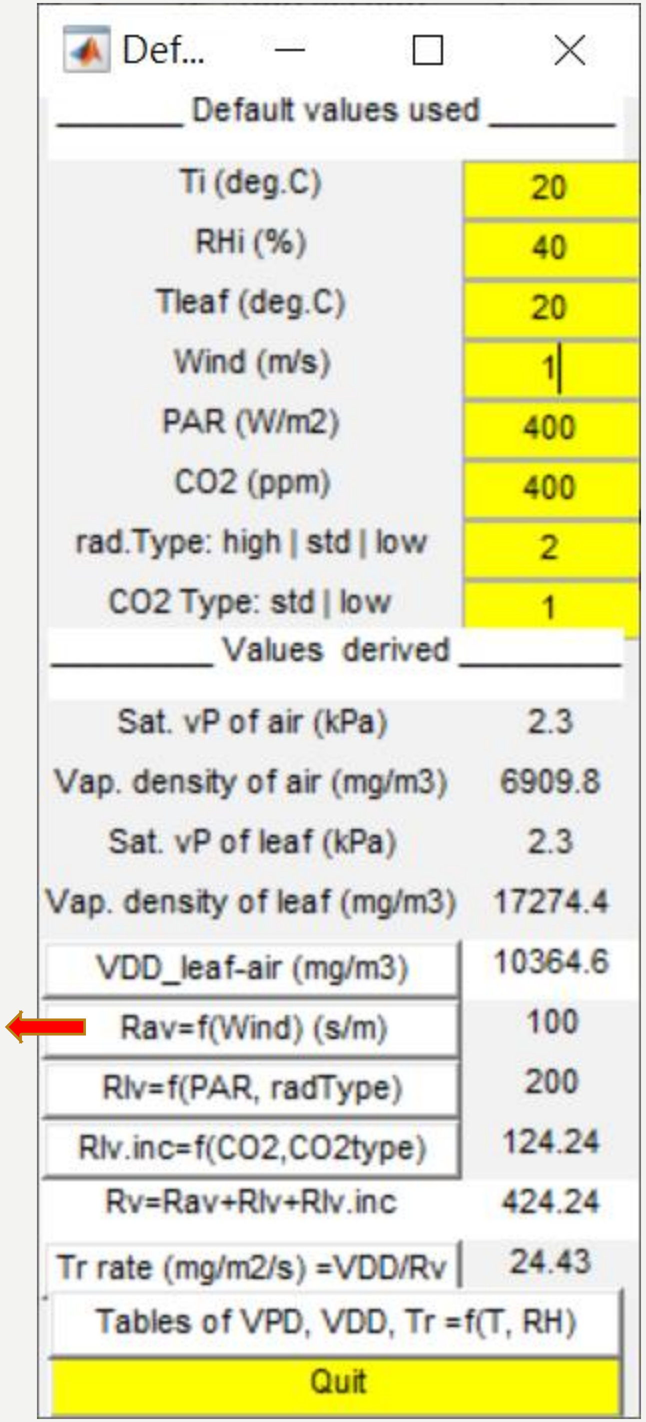


風速影響水汽進出氣孔的阻力

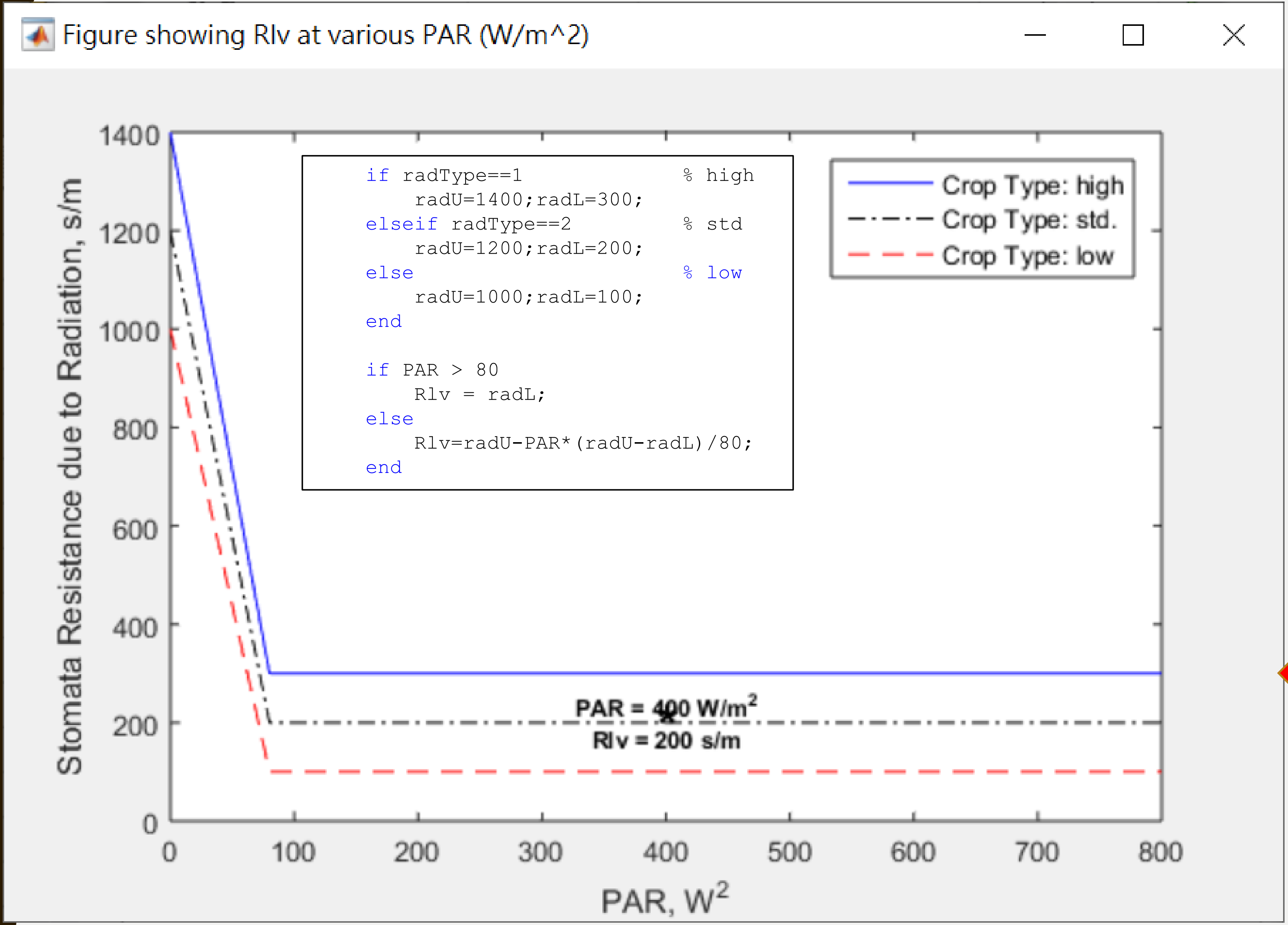
R_{av} 邊界層阻力

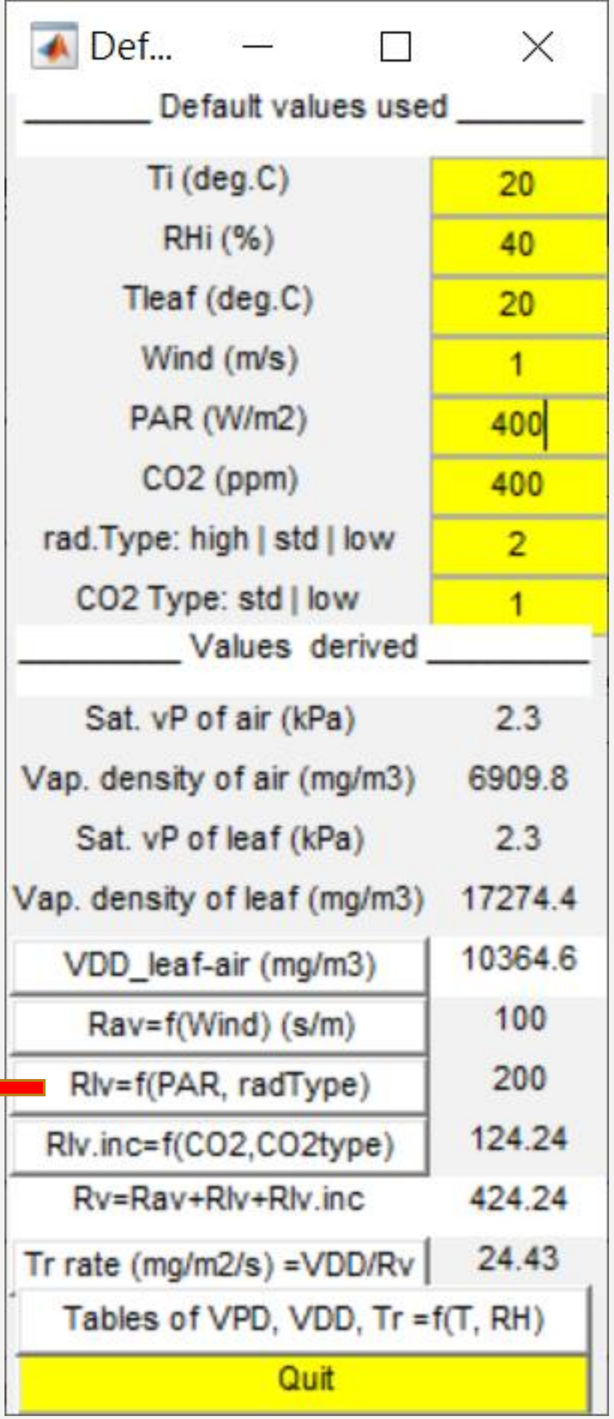
```
if Wind >= 1
        Rav=100;
    else
        Rav=200-(Wind*100);
end
```





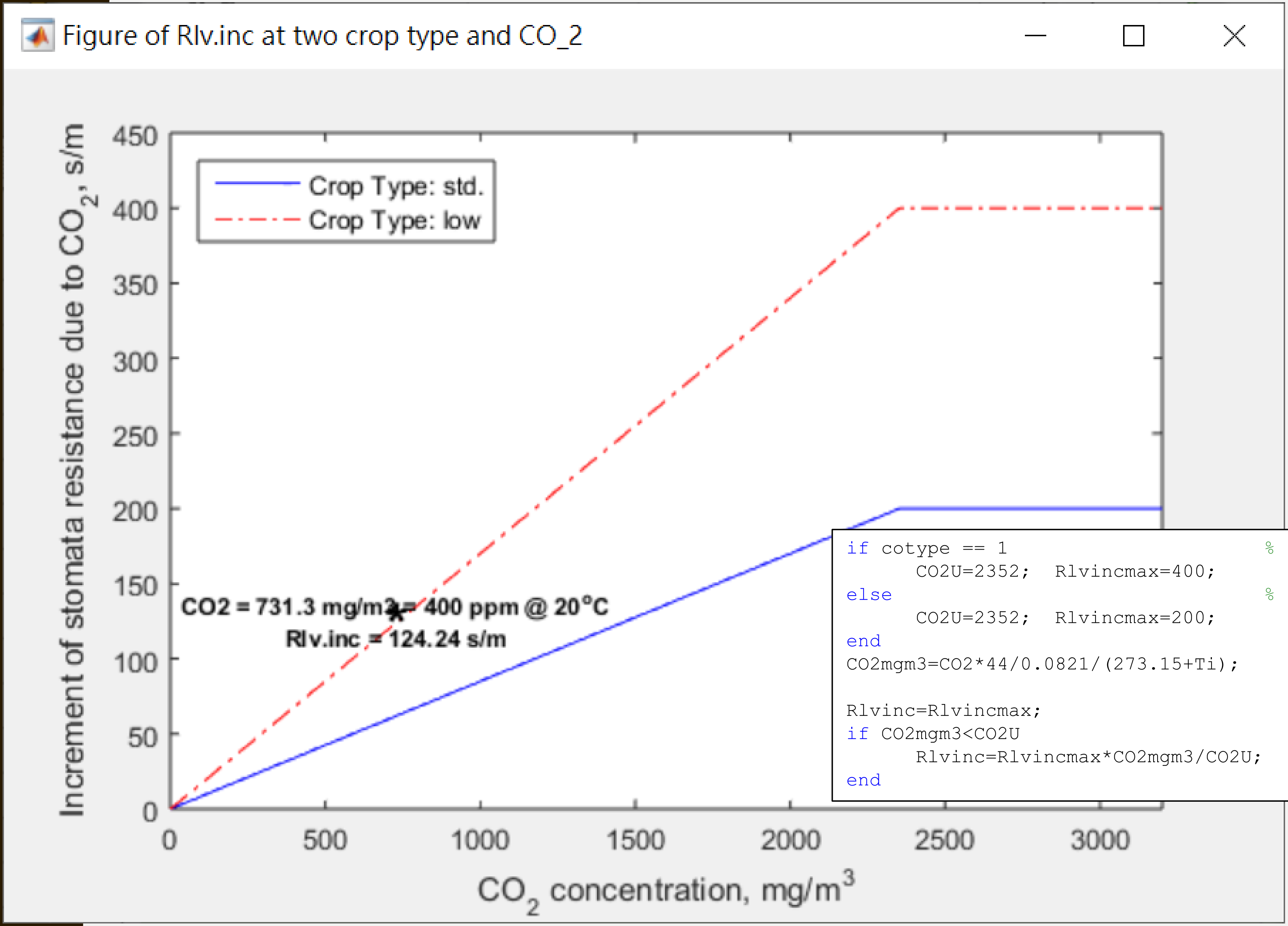
光量影響水汽進出氣孔的阻力 R_{lv}





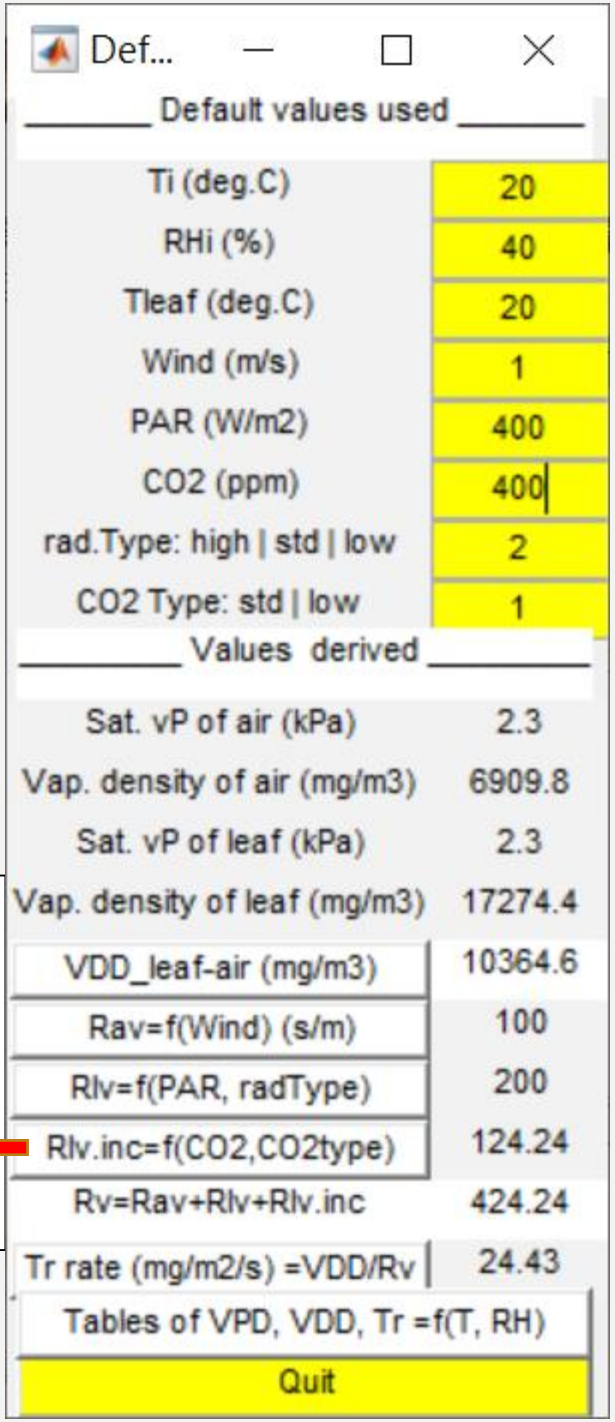
Default values used	D	D	D
Ti (deg.C)	20	20	20
RHi (%)	40	40	40
Tleaf (deg.C)	20	20	20
Wind (m/s)	1	1	0.1
PAR (W/m2)	60	400	400
CO2 (ppm)	400	400	1000
rad.Type (high | std | low)	2	2	2
CO2 Type (std | low)	1	1	1
Values derived			
Ps.air (kPa)	2.3	2.3	2.3
VDair (mg/m3)	6909.8	6909.8	6909.8
Ps.leaf (kPa)	2.3	2.3	2.3
VDleaf (mg/m3)	17274.4	17274.4	17274.4
VDD (mg/m3)	10364.6	10364.6	10364.6
Rav (s/m)	100	100	190
Rlv (s/m)	450	200	200
Rlv.inc (s/m)	124.37	124.37	310.92
Rv total (s/m)	674.37	424.37	700.92
Tr rate (mg/m2/s)	15.37	24.42	14.79
	Quit	Quit	Quit

二氧化碳濃度影響水汽進出氣孔的阻力 $R_{lv.inc}$




```
if cotype == 1                              % std
      CO2U=2352;  Rlvincmax=400;
else                                        % low
      CO2U=2352;  Rlvincmax=200;
end
CO2mgm3=CO2*44/0.0821/(273.15+Ti);

Rlvinc=Rlvincmax;
if CO2mgm3<CO2U
      Rlvinc=Rlvincmax*CO2mgm3/CO2U;
end
```



	D	D	D	D
Default values used				
Ti (deg.C)	20	20	20	20
RHi (%)	40	40	40	40
Tleaf (deg.C)	20	20	20	20
Wind (m/s)	1	1	1	1
PAR (W/m2)	400	400	400	400
CO2 (ppm)	400	400	1200	1200
rad.Type (high | std | low)	2	2	2	2
CO2 Type (std | low)	2	1	1	2
Values derived				
Ps.air (kPa)	2.3	2.3	2.3	2.3
VDair (mg/m3)	6909.8	6909.8	6909.8	6909.8
Ps.leaf (kPa)	2.3	2.3	2.3	2.3
VDleaf (mg/m3)	17274.4	17274.4	17274.4	17274.4
VDD (mg/m3)	10364.6	10364.6	10364.6	10364.6
Rav (s/m)	100	100	100	100
Rlv (s/m)	200	200	200	200
Rlv.inc (s/m)	62.18	124.37	373.1	186.55
Rv total (s/m)	362.18	424.37	673.1	486.55
Tr rate (mg/m2/s)	28.62	24.42	15.4	21.3
	Quit	Quit	Quit	Quit

CO_2單位轉換：ppm, mg/m^3, mg/kg

$P V = n R T = (m/M) R T$

when $P = 1$, $V = m R T / M$

density = m / V = $M / (R T)$

@0°C = 44/(0.0821*273.15) = 1.96 mg CO_2/m^3 air @ 1 TAM

=44/(0.083144*273.15) = 1.9374 @ 1 bar

@20°C = 44/(0.0821*(273.15+20)) = 1.83 mg CO_2/m^3 air

1 ppm = 1 m^3 CO_2/10^6 m^3 air = 1.96 mg/m^3 air @ 0°C

= 1.96/density of air = 1.96/1.29 = 1.519 mg/kg@ 0°C

TrSimulator.m

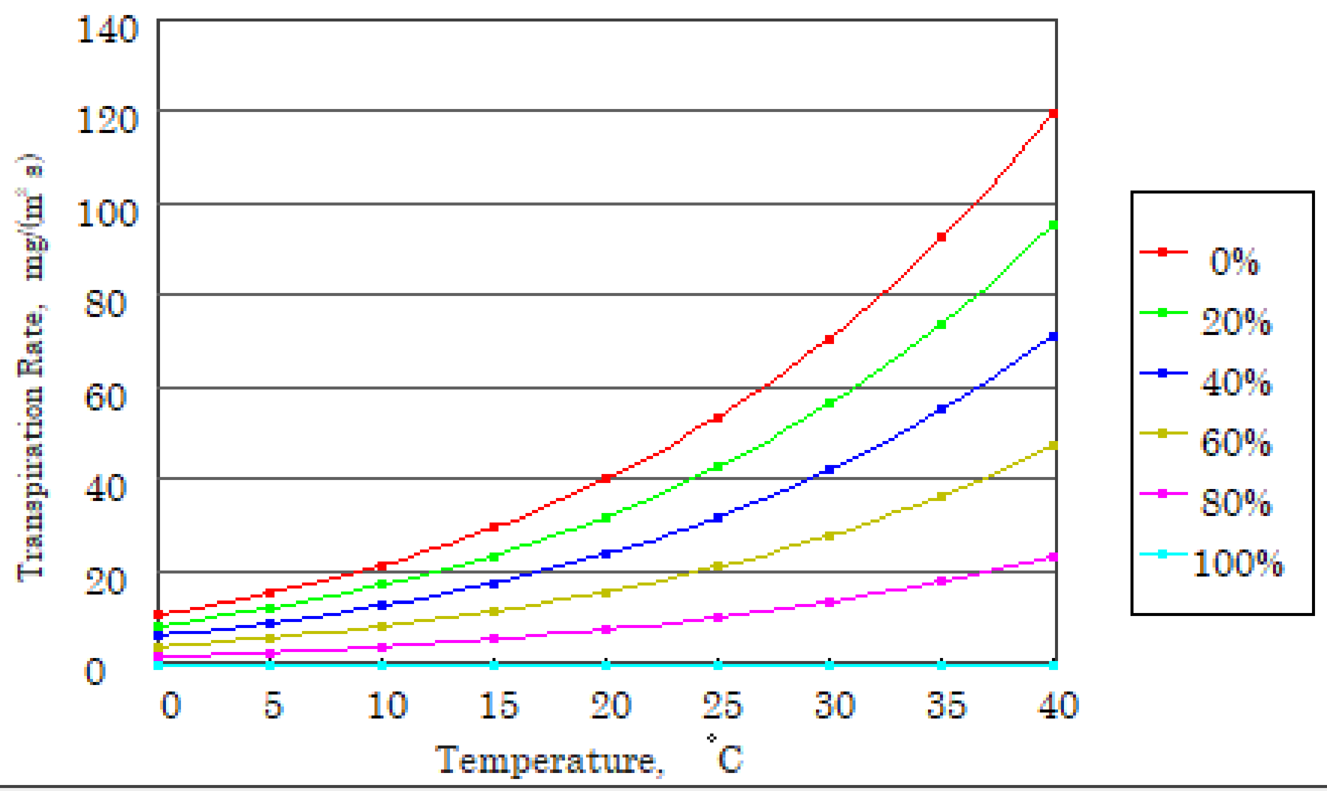
Default values used	
Ti (deg.C)	25
RHi (%)	20
Tleaf (deg.C)	25
Wind (m/s)	1
PAR (W/m2)	400
CO2 (ppm)	400
rad.Type (high | std | low)	2
CO2 Type (std | low)	1
Values derived	
Ps.air (kPa)	3.2
VDair (mg/m3)	4601.9
Ps.leaf (kPa)	3.2
VDleaf (mg/m3)	23009.6
VDD (mg/m3)	18407.6
Rav (s/m)	100
Rlv (s/m)	200
Rlv.inc (s/m)	122.28
Rv total (s/m)	422.28
Tr rate (mg/m2/s)	43.59

Quit

Relative humidity and Transpiration rate at various temperatures

(Ip 400 W/m^2 , Wind 1 m/s , CO2 conc. 732 mg/m^3)

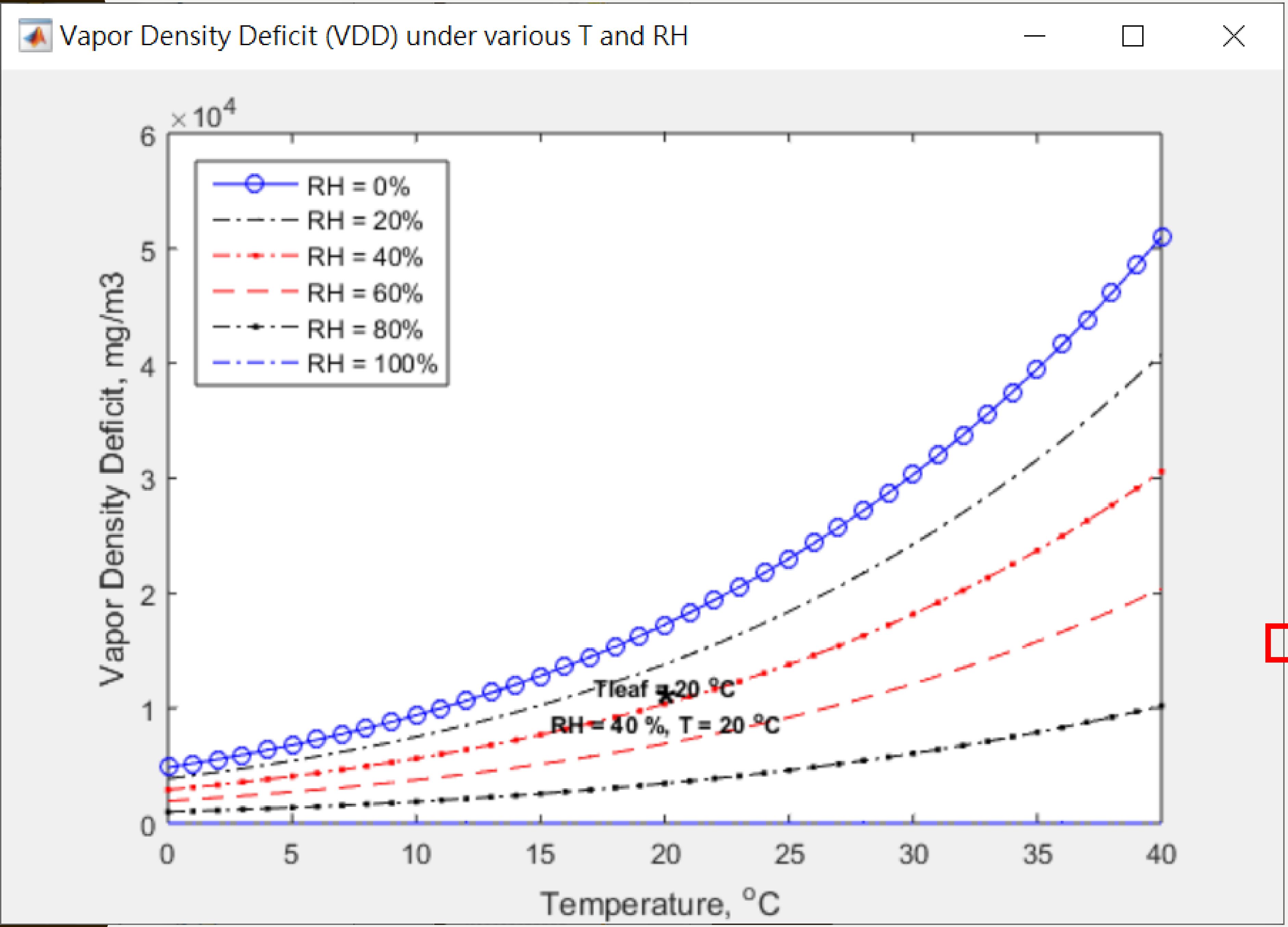
RH, %	Temperature, °C 0	5	10	15	20	25	30	35	40
0	11.41	16.00	22.13	30.19	40.69	54.20	71.40	93.08	120.15
20	9.13	12.80	17.70	24.15	32.55	43.36	57.12	74.47	96.12
40	6.85	9.60	13.28	18.12	24.42	32.52	42.84	55.85	72.09
60	4.56	6.40	8.85	12.08	16.28	21.68	28.56	37.23	48.06
80	2.28	3.20	4.43	6.04	8.14	10.84	14.28	18.62	24.03
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



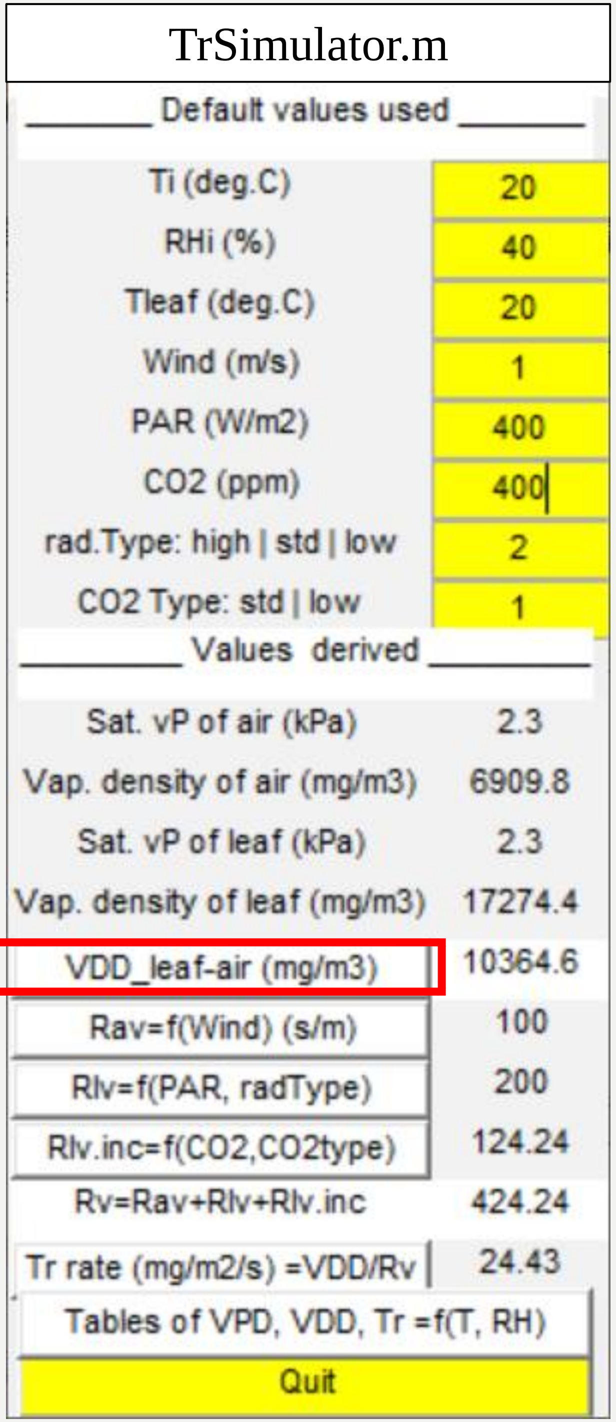
TrSimulator.m

Default values used	
Ti (deg.C)	20
RHi (%)	40
Tleaf (deg.C)	20
Wind (m/s)	1
PAR (W/m2)	400
CO2 (ppm)	400
rad.Type (high | std | low)	2
CO2 Type (std | low)	1
Values derived	
Ps.air (kPa)	2.3
VDair (mg/m3)	6909.8
Ps.leaf (kPa)	2.3
VDleaf (mg/m3)	17274.4
VDD (mg/m3)	10364.6
Rav (s/m)	100
Rlv (s/m)	200
Rlv.inc (s/m)	124.37
Rv total (s/m)	424.37
Tr rate (mg/m2/s)	24.42

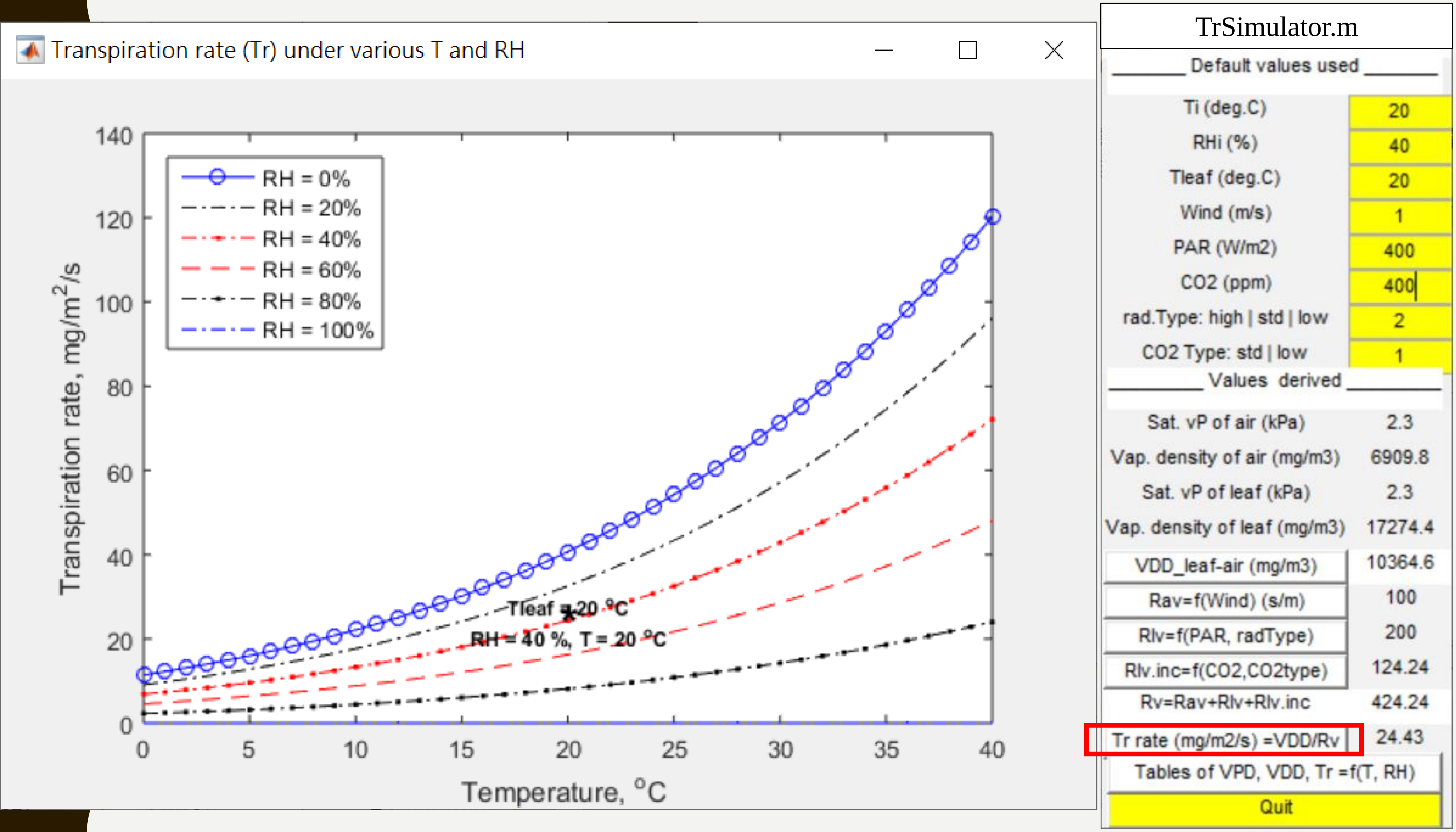
Quit

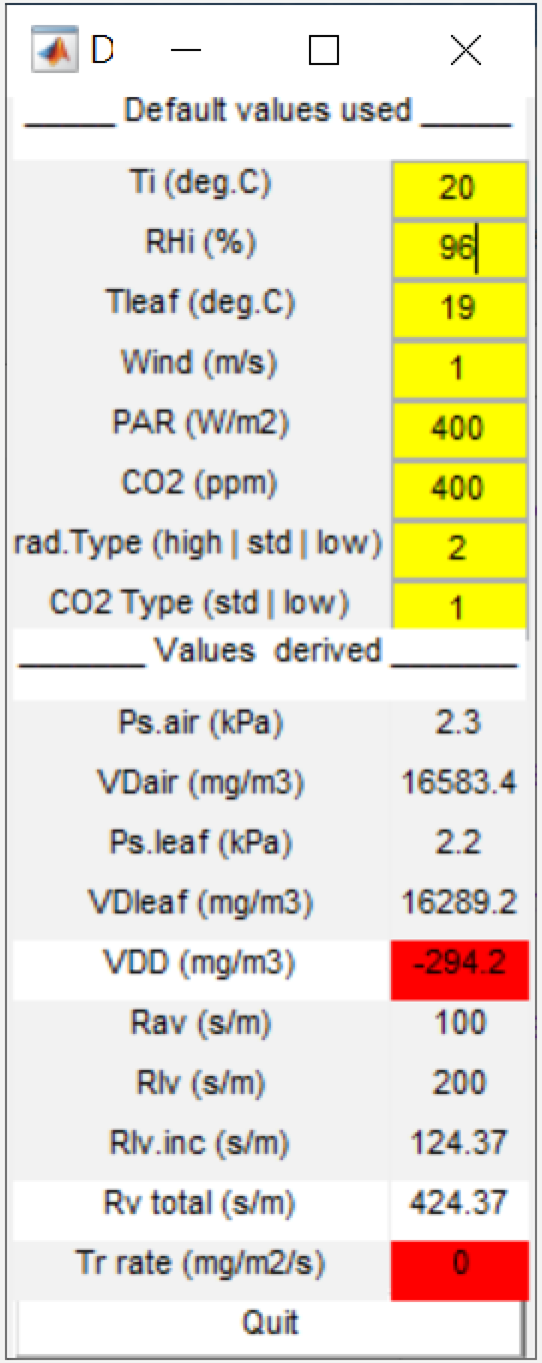


Vapor Density Deficit (VDD) under various T and RH
× 10^4
Vapor Density Deficit, mg/m3
Temperature, °C
RH = 0%
RH = 20%
RH = 40%
RH = 60%
RH = 80%
RH = 100%
Tleaf = 20 °C
RH = 40 %, T = 20 °C
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
40



TrSimulator.m
Default values used
Ti (deg.C) 20
RHi (%) 40
Tleaf (deg.C) 20
Wind (m/s) 1
PAR (W/m2) 400
CO2 (ppm) 400
rad.Type: high | std | low 2
CO2 Type: std | low 1
Values derived
Sat. vP of air (kPa) 2.3
Vap. density of air (mg/m3) 6909.8
Sat. vP of leaf (kPa) 2.3
Vap. density of leaf (mg/m3) 17274.4
VDD_leaf-air (mg/m3) 10364.6
Rav=f(Wind) (s/m) 100
Rlv=f(PAR, radType) 200
Rlv.inc=f(CO2,CO2type) 124.24
Rv=Rav+Rlv+Rlv.inc 424.24
Tr rate (mg/m2/s) =VDD/Rv 24.43
Tables of VPD, VDD, Tr =f(T, RH)
Quit


Transpiration rate (Tr) under various T and RH
Transpiration rate, mg/m2/s
Temperature, °C
RH = 0%
RH = 20%
RH = 40%
RH = 60%
RH = 80%
RH = 100%
Tleaf = 20 °C
RH = 40 %, T = 20 °C
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30
35
40
TrSimulator.m
Default values used
Ti (deg.C)
20
RHi (%)
40
Tleaf (deg.C)
20
Wind (m/s)
1
PAR (W/m2)
400
CO2 (ppm)
400
rad.Type: high | std | low
2
CO2 Type: std | low
1
Values derived
Sat. vP of air (kPa)
2.3
Vap. density of air (mg/m3)
6909.8
Sat. vP of leaf (kPa)
2.3
Vap. density of leaf (mg/m3)
17274.4
VDD_leaf-air (mg/m3)
10364.6
Rav=f(Wind) (s/m)
100
Rlv=f(PAR, radType)
200
Rlv.inc=f(CO2,CO2type)
124.24
Rv=Rav+Rlv+Rlv.inc
424.24
Tr rate (mg/m2/s) =VDD/Rv
24.43
Tables of VPD, VDD, Tr =f(T, RH)
Quit



軟體的貼心設計

- $Tr = VDD / R_{v.total}$

- 正常狀態下當 VDD > 0，Tr > 0
  - 代表水汽會由氣孔擴散到葉片外

- 特殊狀態下，譬如高濕的環境， VDD < 0
  - 雖然上式的計算結果 Tr < 0 但不代表水汽會由葉片外進入氣孔，此時的Tr 應強制設定為 0
  - 代表氣孔可能關閉，此時無蒸散作用發生。

軟體也提供3個表格

$$VPD = f(T_{air}, RH_{air}) \qquad VDD = f(T_{air}, RH_{air})$$

$$Tr = f(T_{air}, RH_{air})$$

Command Window

程式可自動切換到 指令視窗

Vapor Pressure Deficit (VPD, in kPa) at various air T and RH

T_air =	0	5	10	15	20	25	30	35	40	deg.C
RH = 0%	0.61	0.87	1.23	1.71	2.34	3.17	4.24	5.62	7.37	kPa
RH = 20%	0.49	0.70	0.98	1.36	1.87	2.53	3.39	4.50	5.90	kPa
RH = 40%	0.37	0.52	0.74	1.02	1.40	1.90	2.55	3.37	4.42	kPa
RH = 60%	0.24	0.35	0.49	0.68	0.94	1.27	1.70	2.25	2.95	kPa
RH = 80%	0.12	0.17	0.25	0.34	0.47	0.63	0.85	1.12	1.47	kPa
RH = 100%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kPa

fx Press 'enter' to continue

按 ‘Enter’ 鍵，可顯示下一個表格

TrSimulator.m

Default values used

Ti (deg.C)	20
RHi (%)	40
Tleaf (deg.C)	20
Wind (m/s)	1
PAR (W/m2)	400
CO2 (ppm)	400
rad.Type: high | std | low	2
CO2 Type: std | low	1

Values derived

Sat. vP of air (kPa)	2.3
Vap. density of air (mg/m3)	6909.8
Sat. vP of leaf (kPa)	2.3
Vap. density of leaf (mg/m3)	17274.4
VDD_leaf-air (mg/m3)	10364.6
Rav=f(Wind) (s/m)	100
Rlv=f(PAR, radType)	200
Rlv.inc=f(CO2,CO2type)	124.24
Rv=Rav+Rlv+Rlv.inc	424.24
Tr rate (mg/m2/s) =VDD/Rv	24.43

Tables of VPD, VDD, Tr =f(T, RH)

Quit

Command Window

Vapor Density Deficit (VDD in mg/m3) at various air T and RH assuming Tair = Tleaf

T_air =	0	5	10	15	20	25	30	35	40	deg.C
RH = 0%	4843.1	6792.2	9392.5	12817.3	17274.4	23009.6	30311.2	39514.4	51005.1	mg/m3
RH = 20%	3874.5	5433.8	7514.0	10253.9	13819.5	18407.6	24249.0	31611.5	40804.1	mg/m3
RH = 40%	2905.9	4075.3	5635.5	7690.4	10364.6	13805.7	18186.7	23708.7	30603.0	mg/m3
RH = 60%	1937.3	2716.9	3757.0	5126.9	6909.8	9203.8	12124.5	15805.8	20402.0	mg/m3
RH = 80%	968.6	1358.4	1878.5	2563.5	3454.9	4601.9	6062.2	7902.9	10201.0	mg/m3
RH = 100%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	mg/m3

fx Press 'enter' to continue

按 'Enter' 鍵，可顯示下一個表格

Command Window

Transpiration Rate (Tr) at various air T and RH assuming Tair = Tleaf
Rav = 424.24 s/m

T_air =	0	5	10	15	20	25	30	35	40	deg.C
RH = 0%	11.42	16.01	22.14	30.21	40.72	54.24	71.45	93.14	120.23	mg/m2/s
RH = 20%	9.13	12.81	17.71	24.17	32.57	43.39	57.16	74.51	96.18	mg/m2/s
RH = 40%	6.85	9.61	13.28	18.13	24.43	32.54	42.87	55.89	72.14	mg/m2/s
RH = 60%	4.57	6.40	8.86	12.09	16.29	21.70	28.58	37.26	48.09	mg/m2/s
RH = 80%	2.28	3.20	4.43	6.04	8.14	10.85	14.29	18.63	24.05	mg/m2/s
RH = 100%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	mg/m2/s

fx 按第三次 'Enter' ，可切換回參數編輯視窗 'enter' to continue

$VPD = f(T_{air}, RH_{air})$ $VDD = f(T_{air}, RH_{air})$ $Tr = f(T_{air}, RH_{air})$

MATLAB 原始碼

```
for j=1:1:6
    rH=20*(j-1);
 for i=1:1:41
   Tp=i-1;
   Psat=0.61078*exp(17.269*Tp/(237.3+Tp));          % vapor pressure in kPa
   VDsat=2166*Psat/(273.16+Tp)*1000;                % vapor density in mg/m3
   VPD(j,i)=Psat*(1-rH/100);          % in kPa
   VDD(j,i)=VDsat*(1-rH/100);         % in mg/m3
   Tr(j,i)=VDD(j,i)/Rv;               % Rv = 424.24 = f(Wind, PAR, CO2, radType, CO2type)
 end  % for i
 end % for j
```

PsSimulator.m

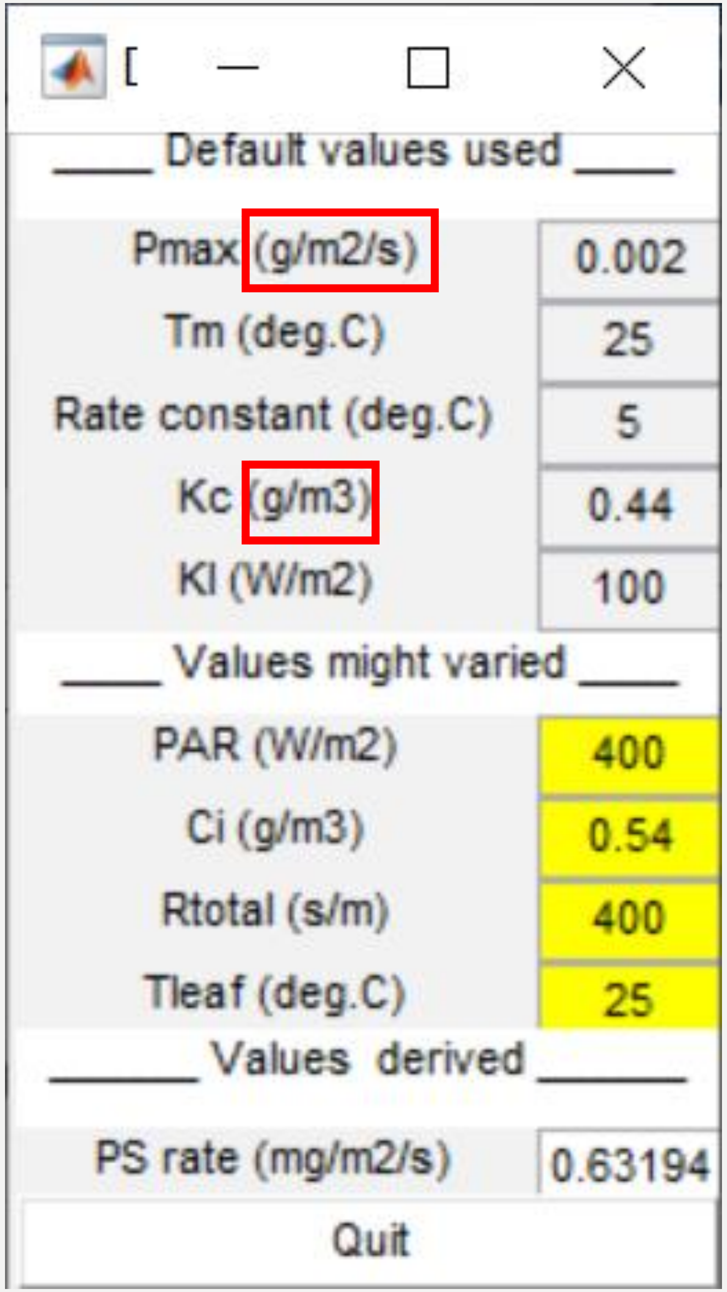
光合速率

PHOTOSYNTHETIC RATE

mol m^{-2} s^{-1}

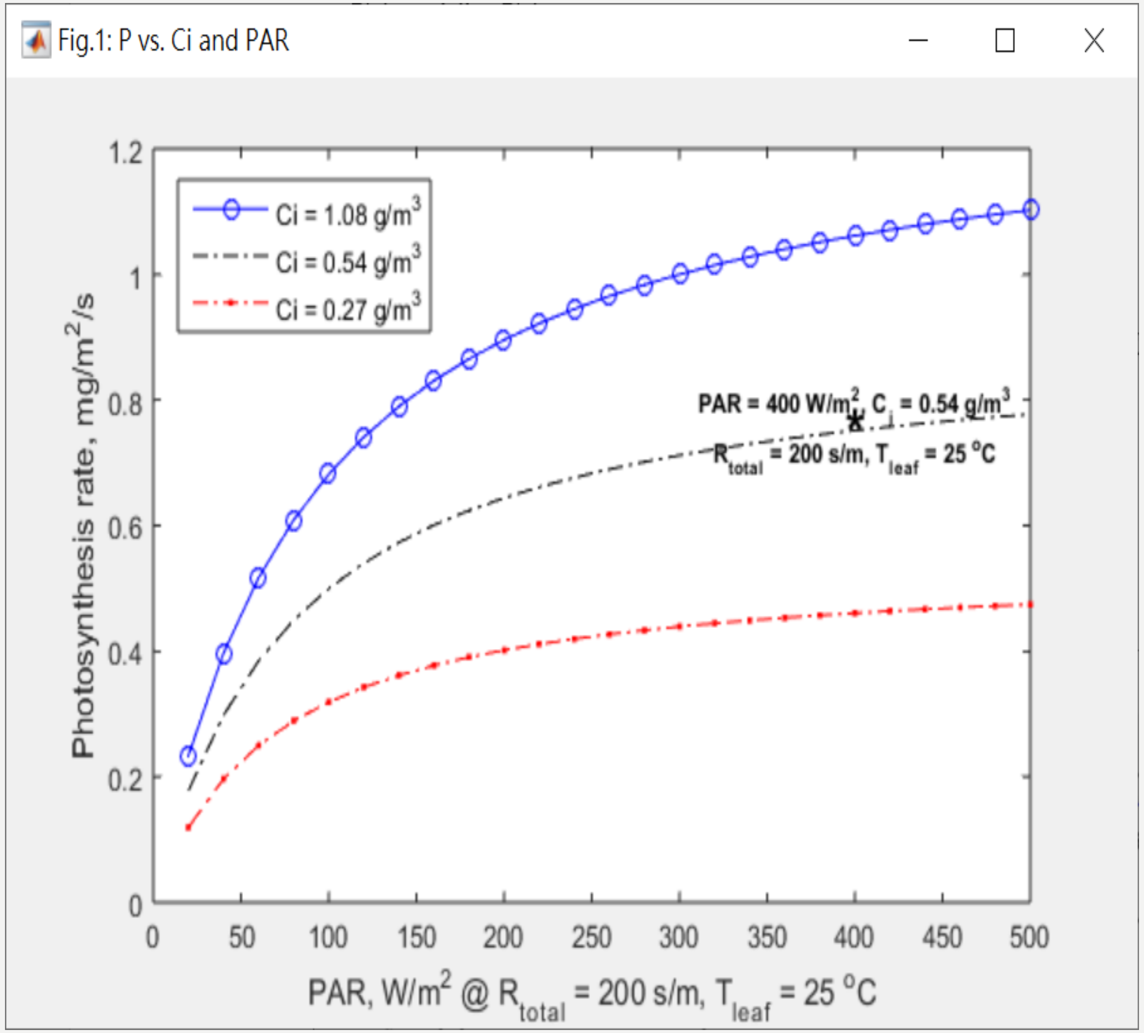
光合速率

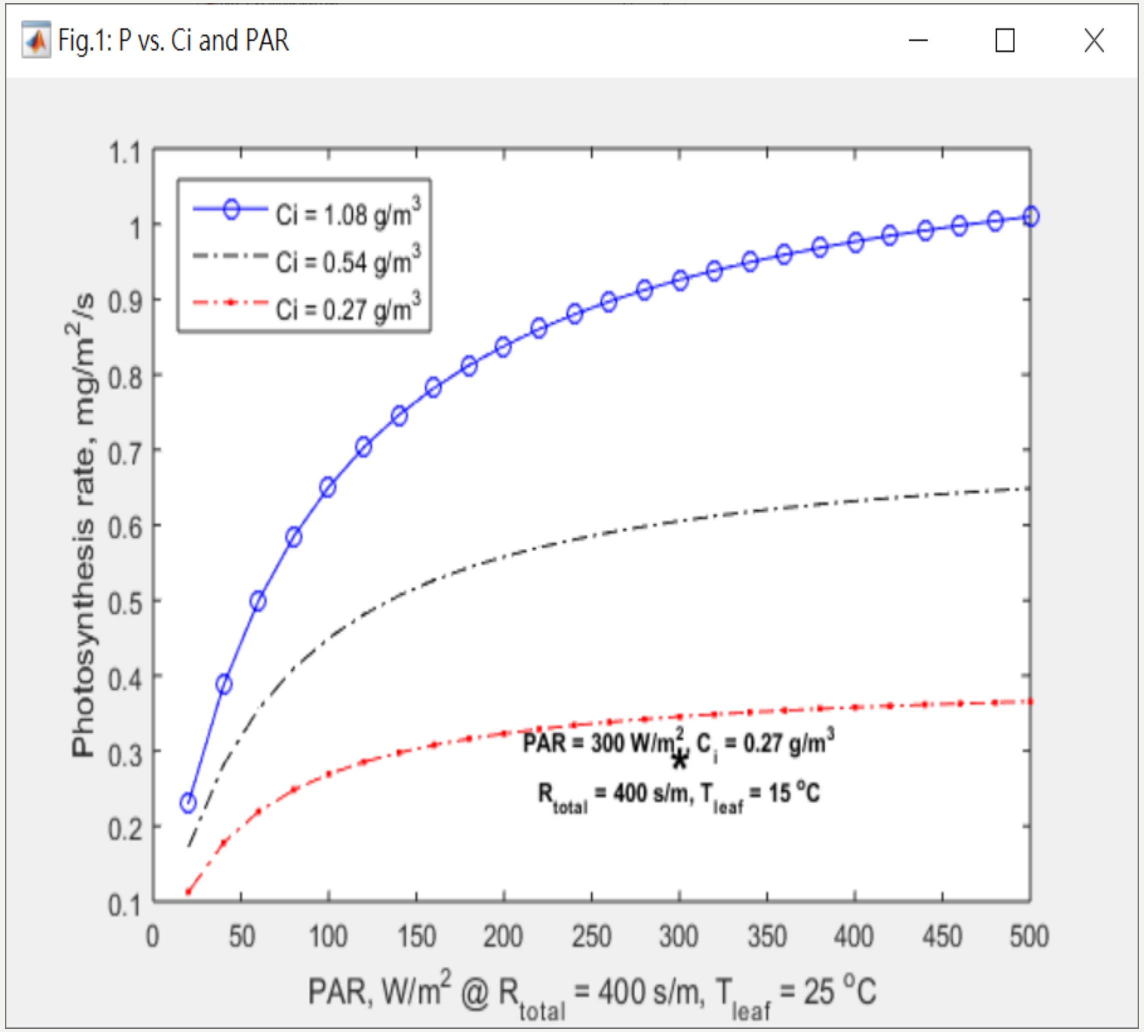
PsSimulator.m



光合速率：1ST WINDOW

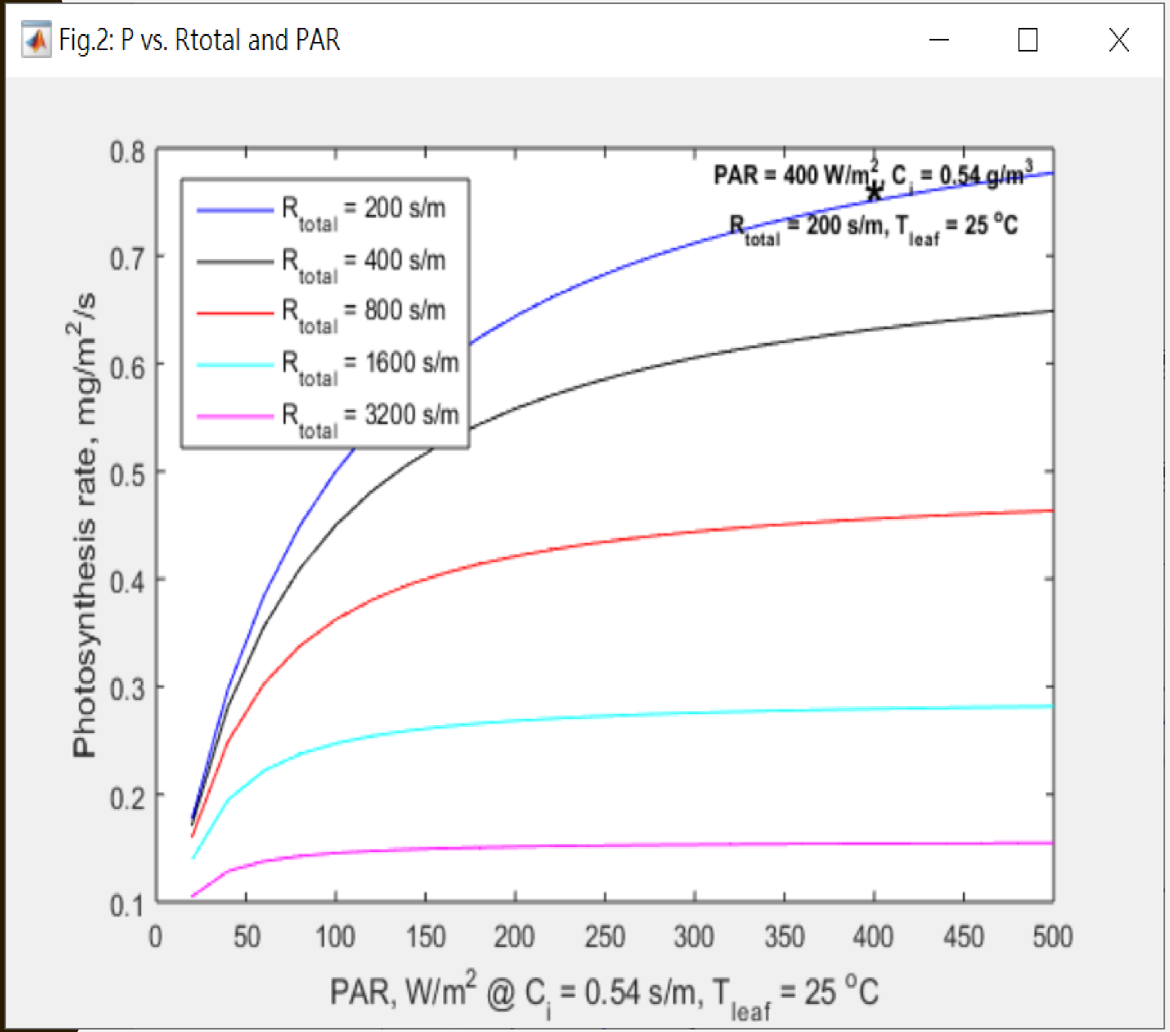
PsSimulator.m

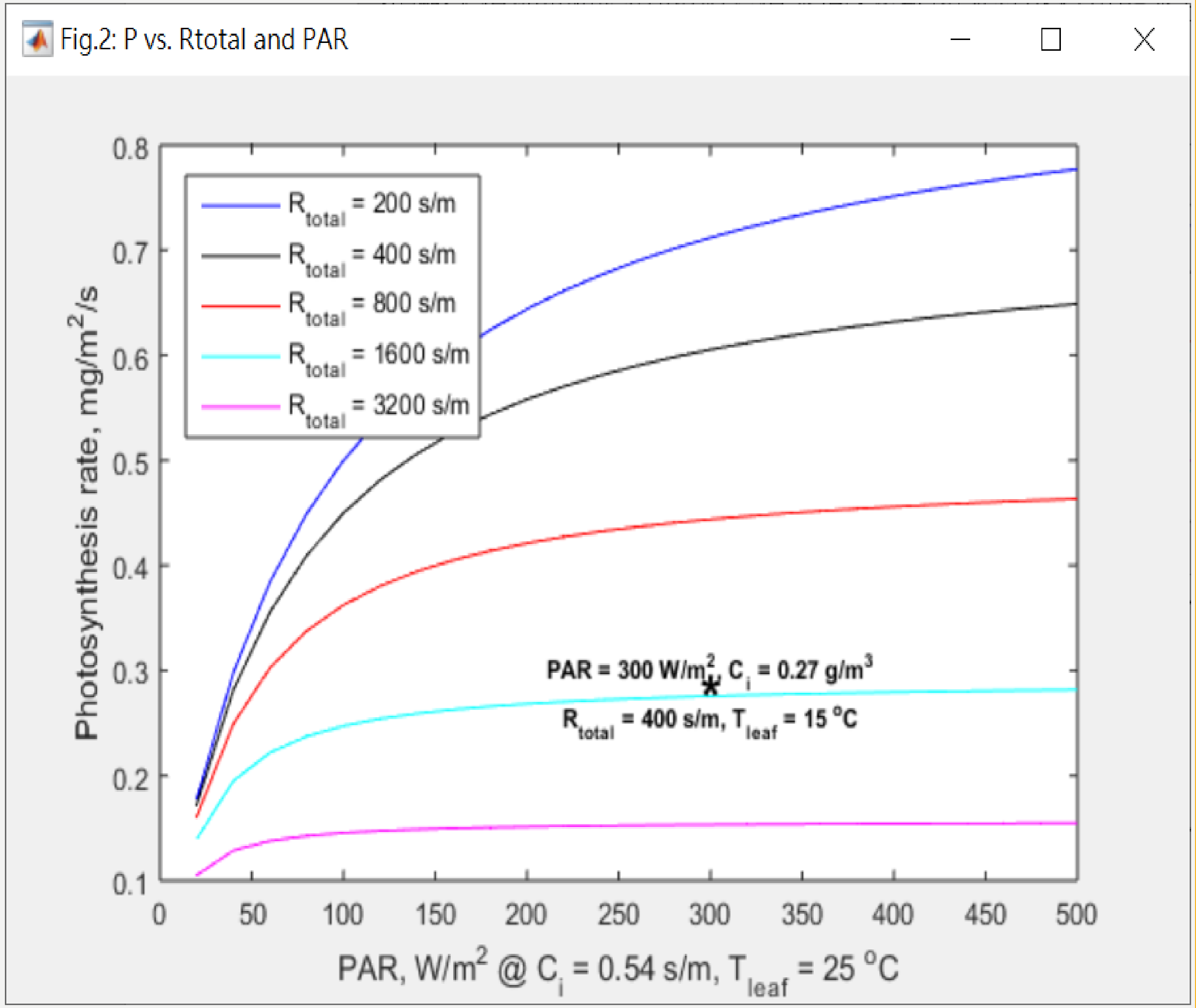




光合速率：2ND WINDOW

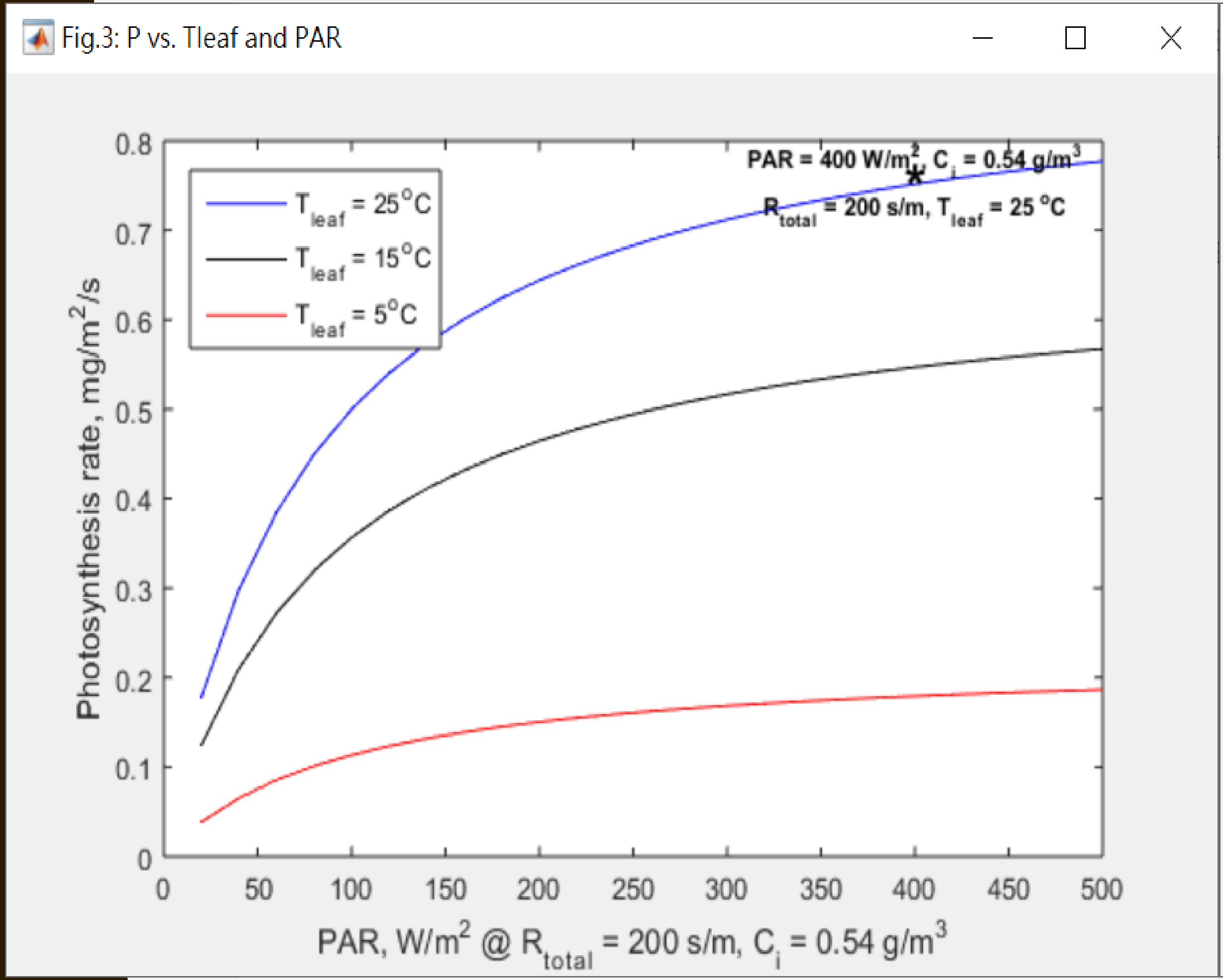
PsSimulator.m

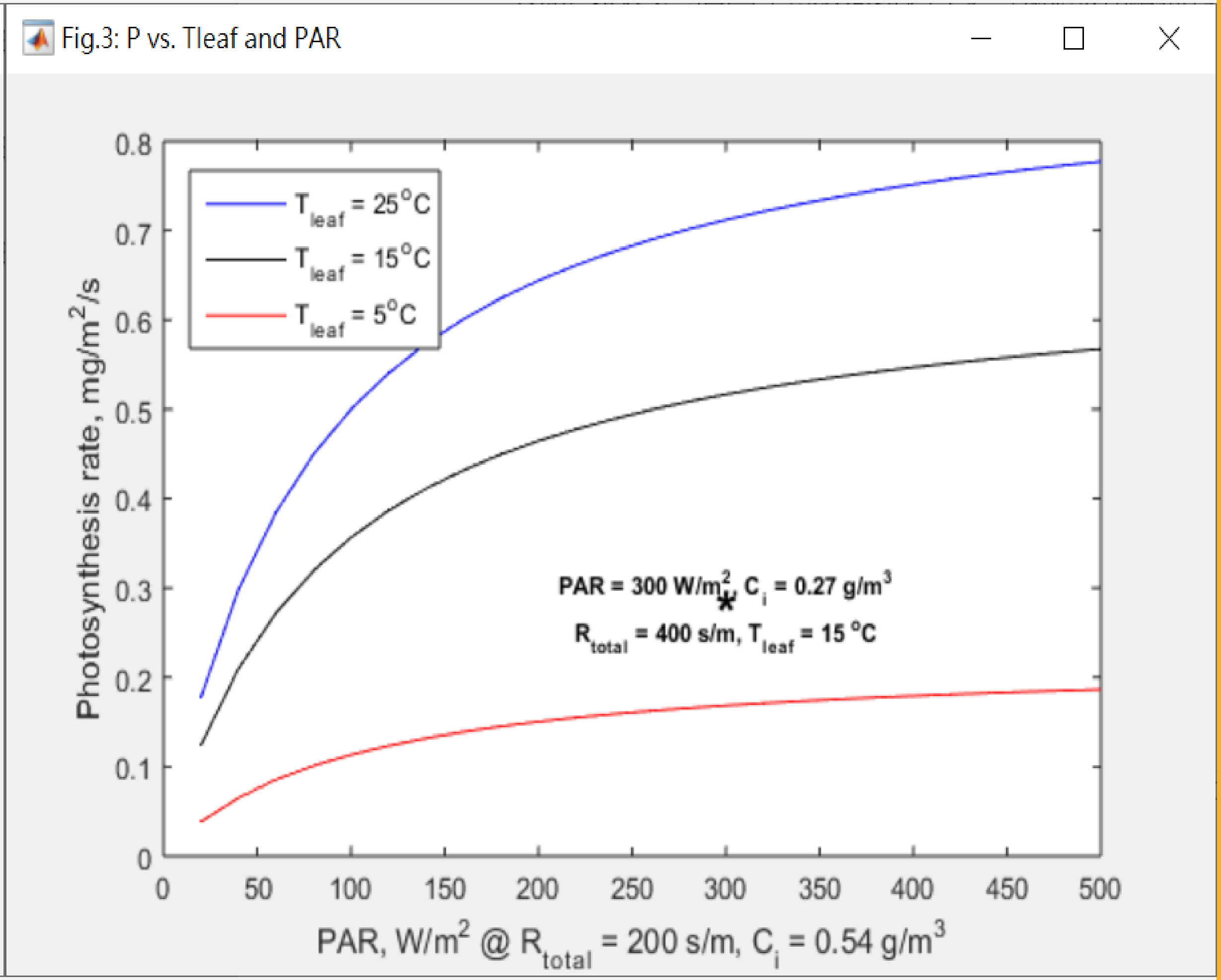




光合速率：3RD WINDOW

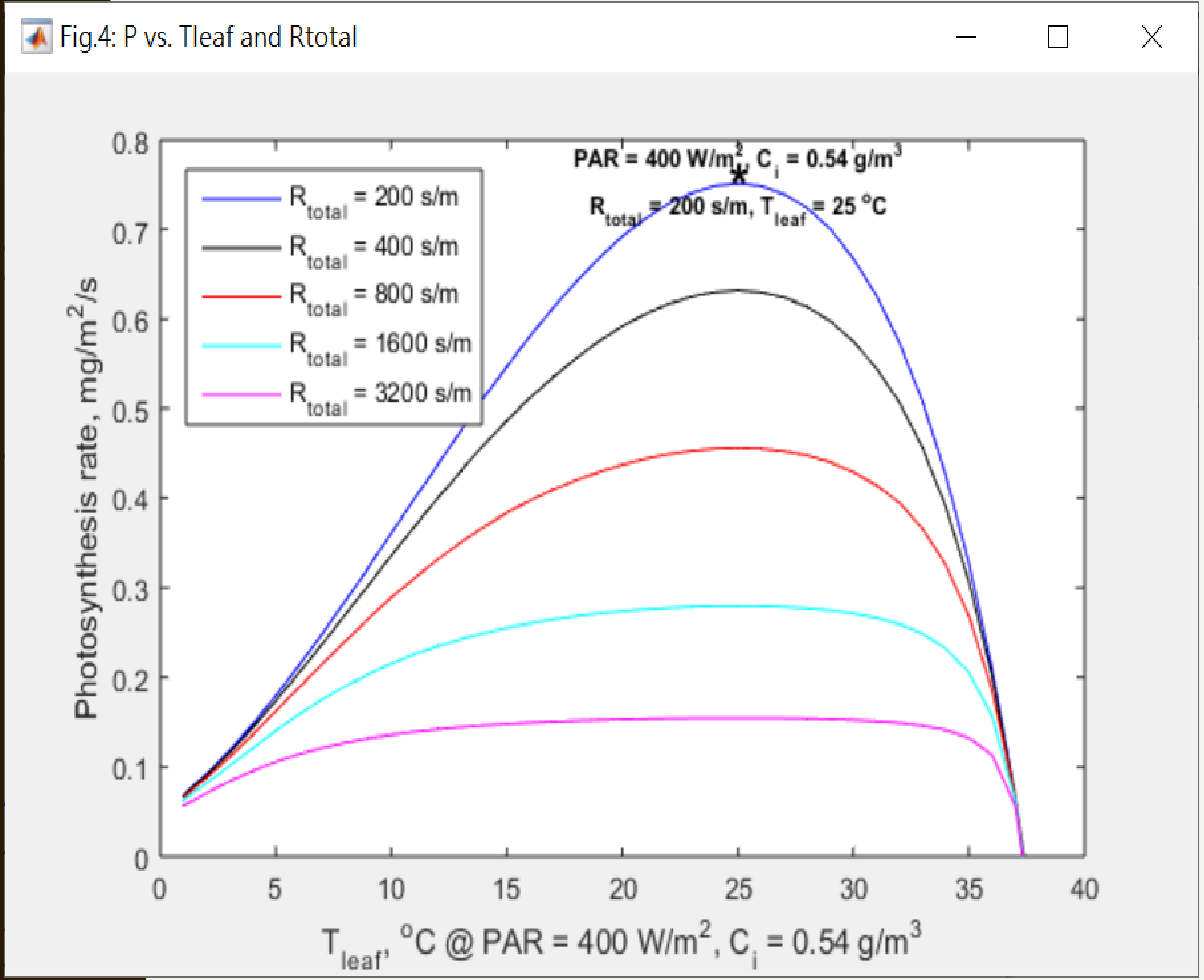
PsSimulator.m

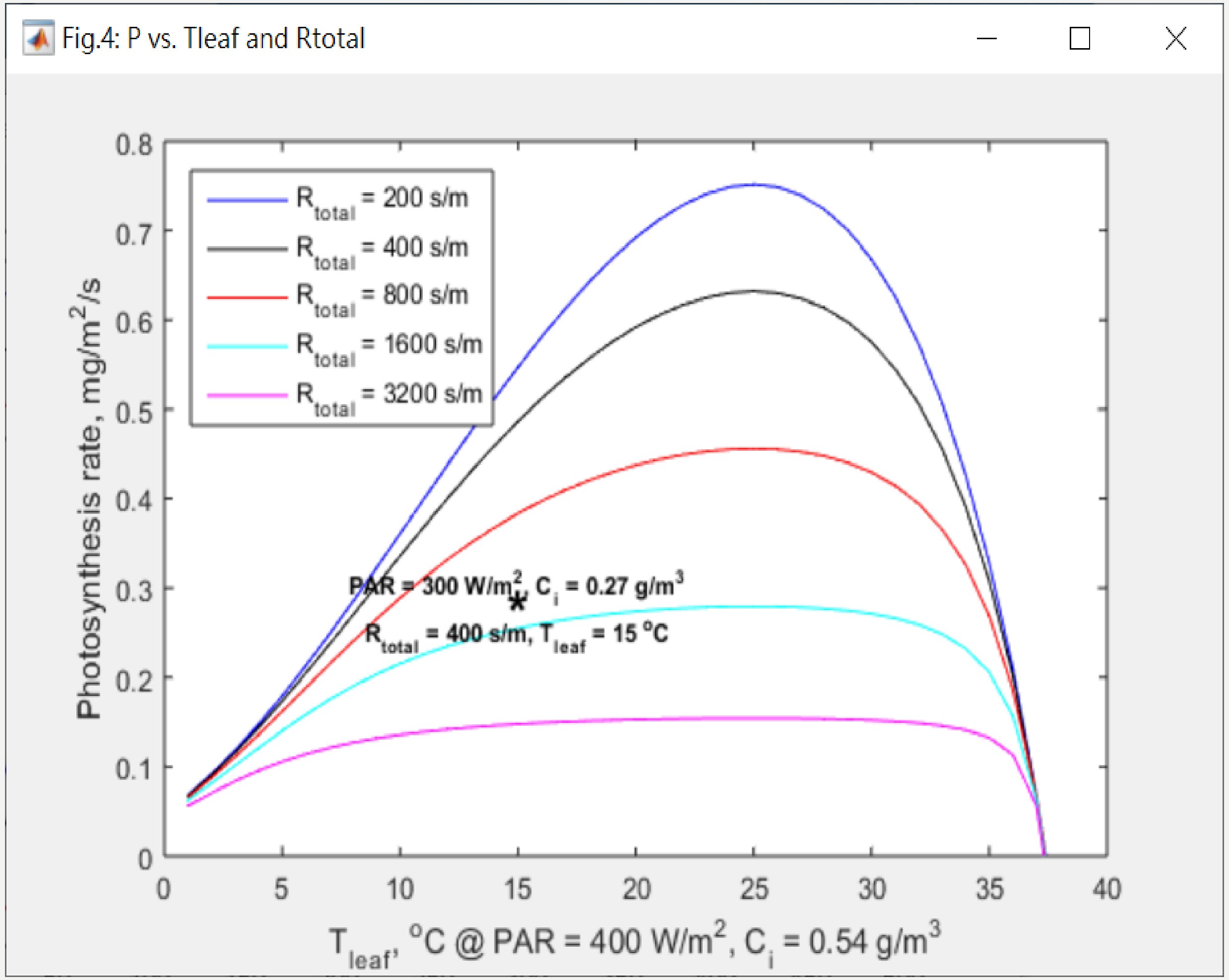




光合速率：4TH WINDOW

PsSimulator.m





PnSimulator.m

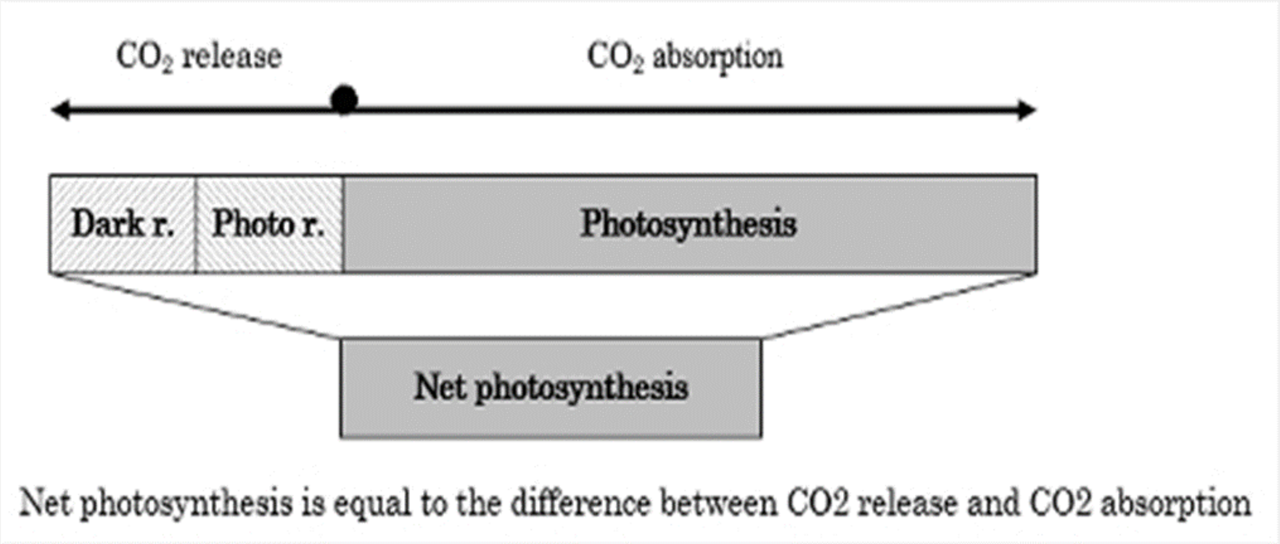
淨光合速率

NET PHOTOSYNTHETIC RATE

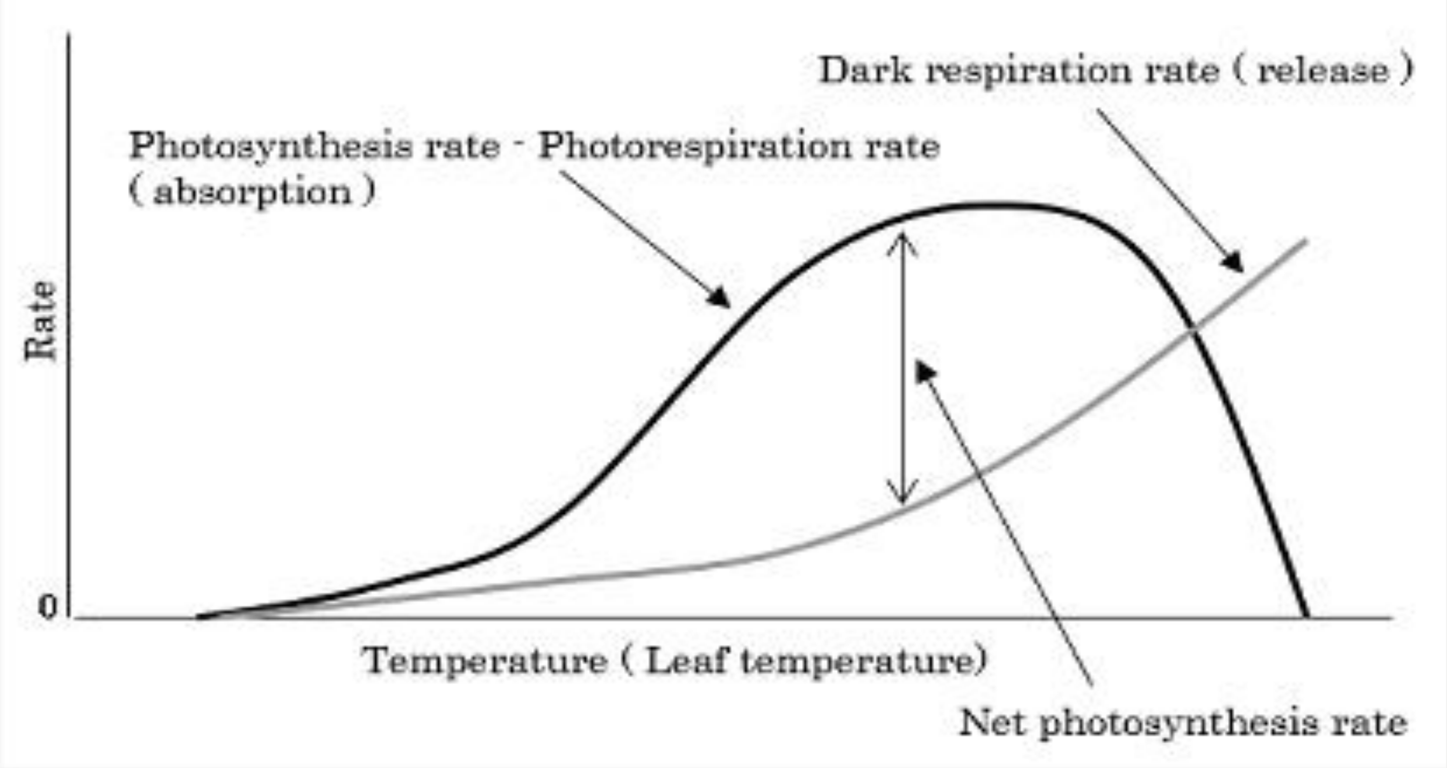
$mg\ m^{-2}\ s^{-1}$

$\mu mol\ m^{-2}\ s^{-1}$

淨光合速率



CO_2 release
CO_2 absorption
Dark r.
Photo r.
Photosynthesis
Net photosynthesis
Net photosynthesis is equal to the difference between CO2 release and CO2 absorption



Dark respiration rate (release)
Photosynthesis rate - Photorespiration rate
(absorption)
Rate
0
Temperature (Leaf temperature)
Net photosynthesis rate

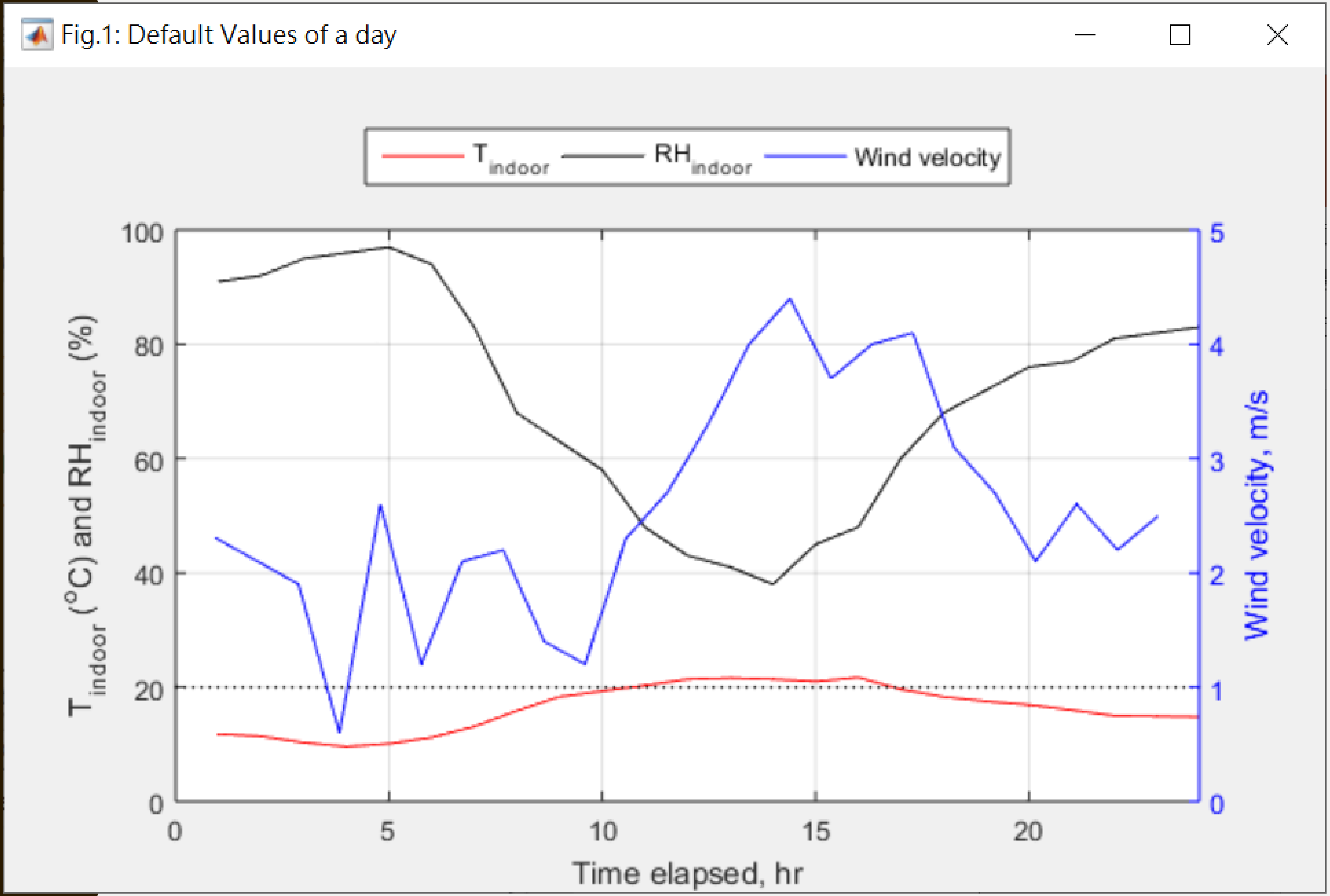


Fig.1: Default Values of a day
T indoor
RH indoor
Wind velocity
T indoor (°C) and RH indoor (%)
Wind velocity, m/s
Time elapsed, hr
0
5
10
15
20
100
80
60
40
20
0
5
4
3
2
1
0

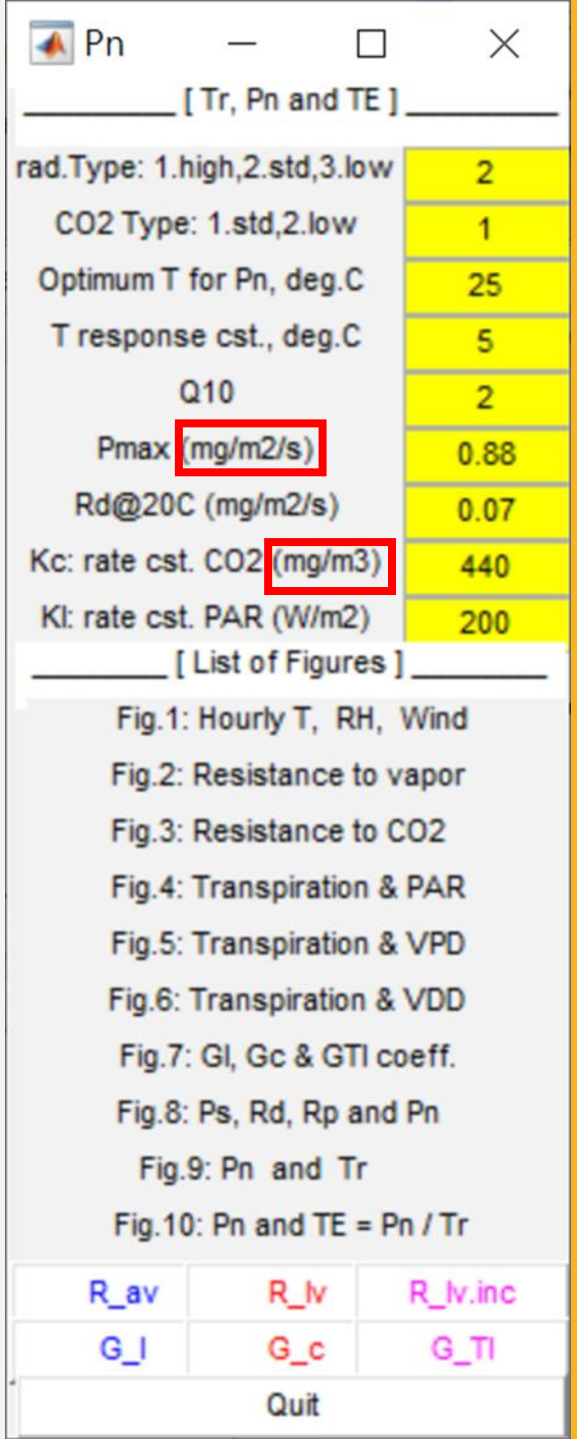

Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.6: Transpiration & VDD
Fig.7: Gl, Gc & GTl coeff.
Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

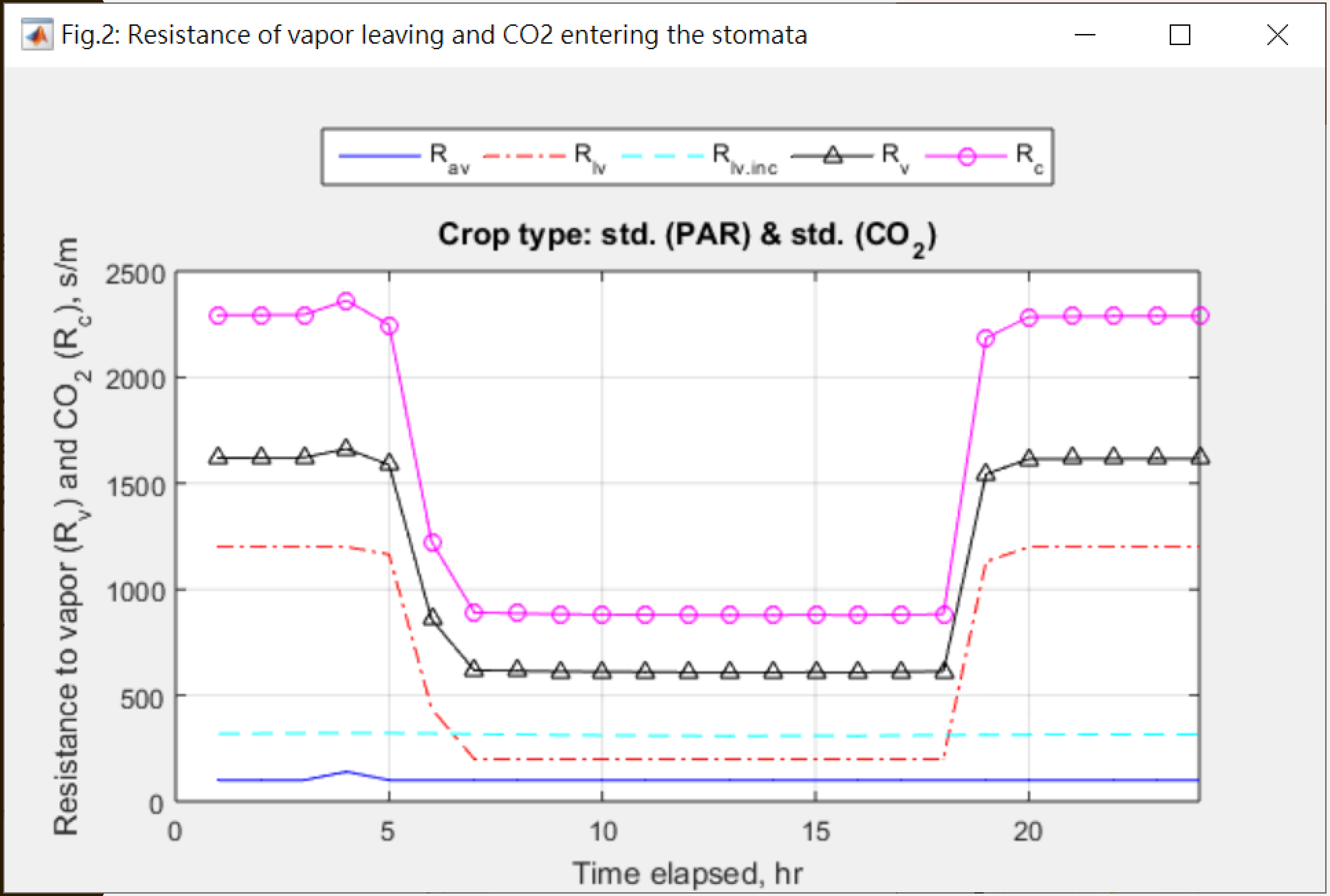
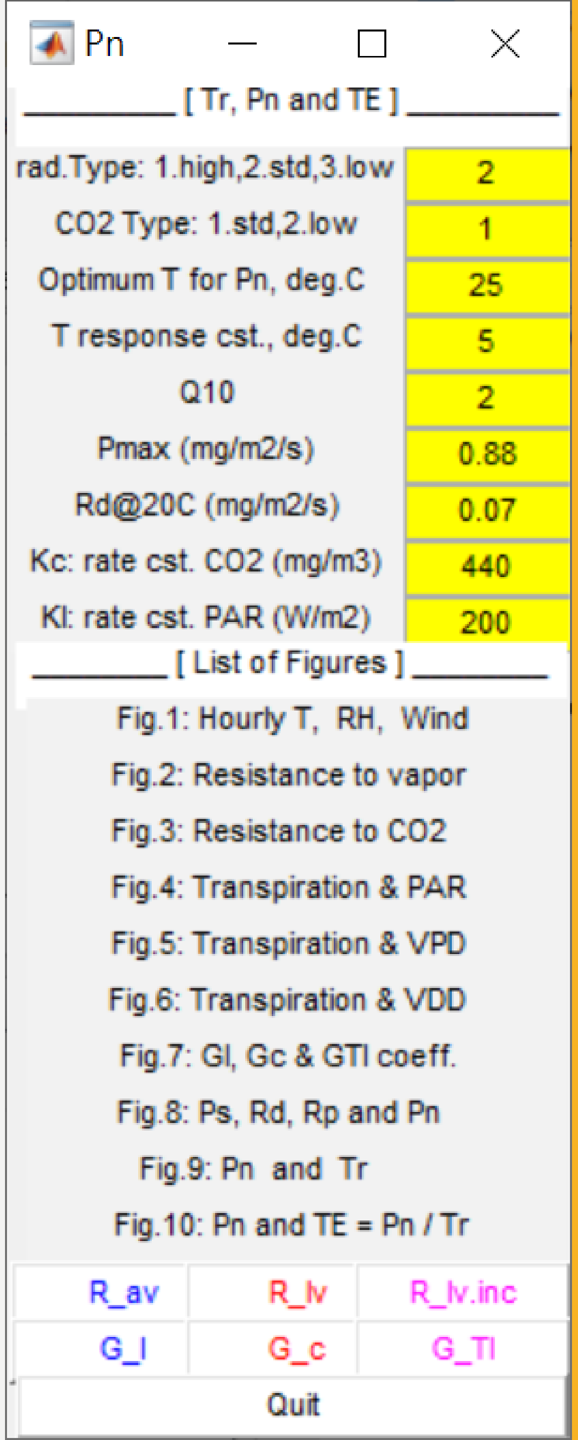


Fig.2: Resistance of vapor leaving and CO2 entering the stomata
R_av
R_lv
R_lv.inc
R_v
R_c
Crop type: std. (PAR) & std. (CO_2)
Resistance to vapor (R_v) and CO_2 (R_c), s/m
2500
2000
1500
1000
500
0
0
5
10
15
20
Time elapsed, hr


Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

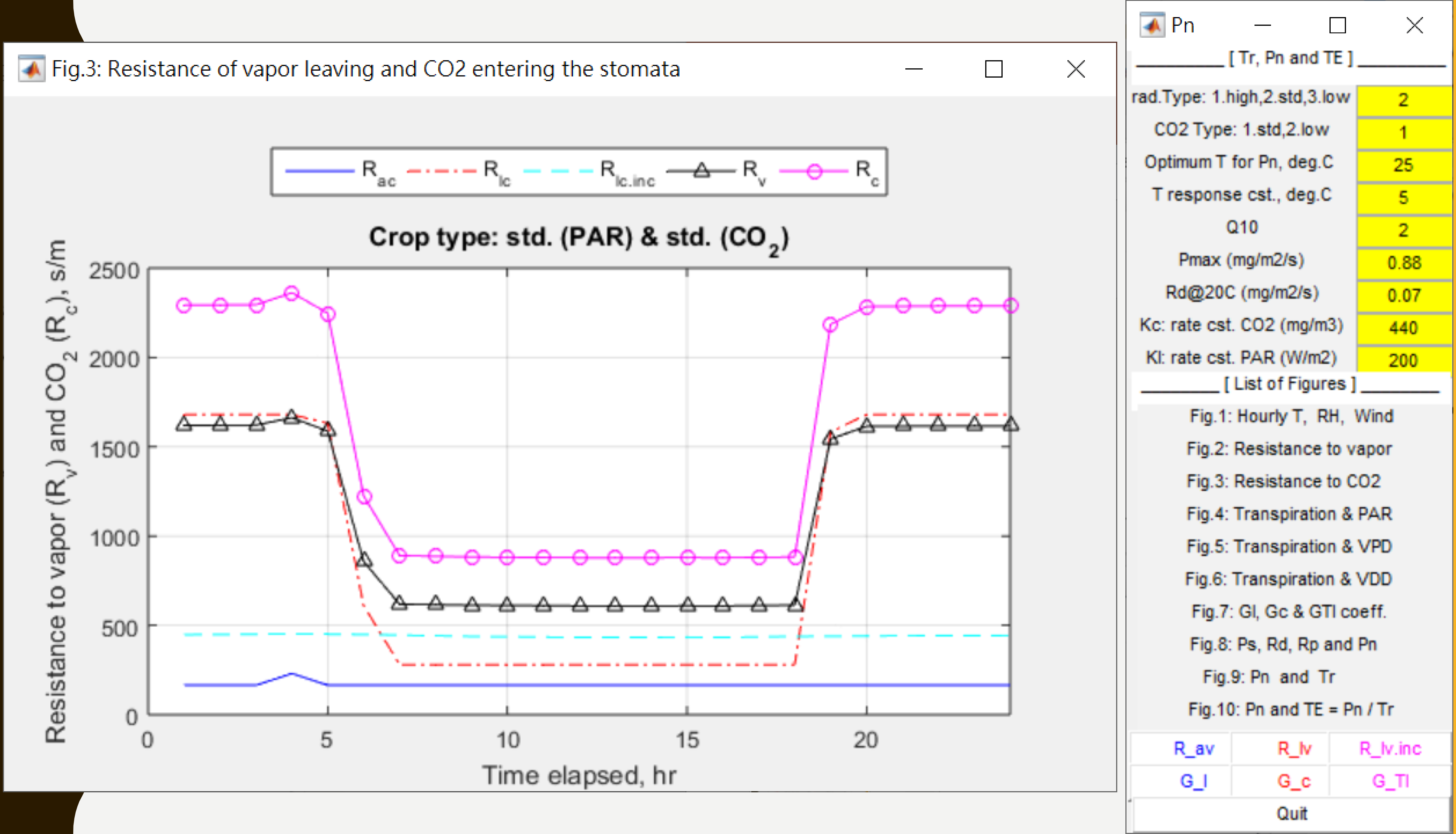
Fig.3: Resistance of vapor leaving and CO2 entering the stomata
R_ac
R_lc
R_lc.inc
R_v
R_c
Crop type: std. (PAR) & std. (CO_2)
Resistance to vapor (R_v) and CO_2 (R_c), s/m
2500
2000
1500
1000
500
0
0
5
10
15
20
Time elapsed, hr
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

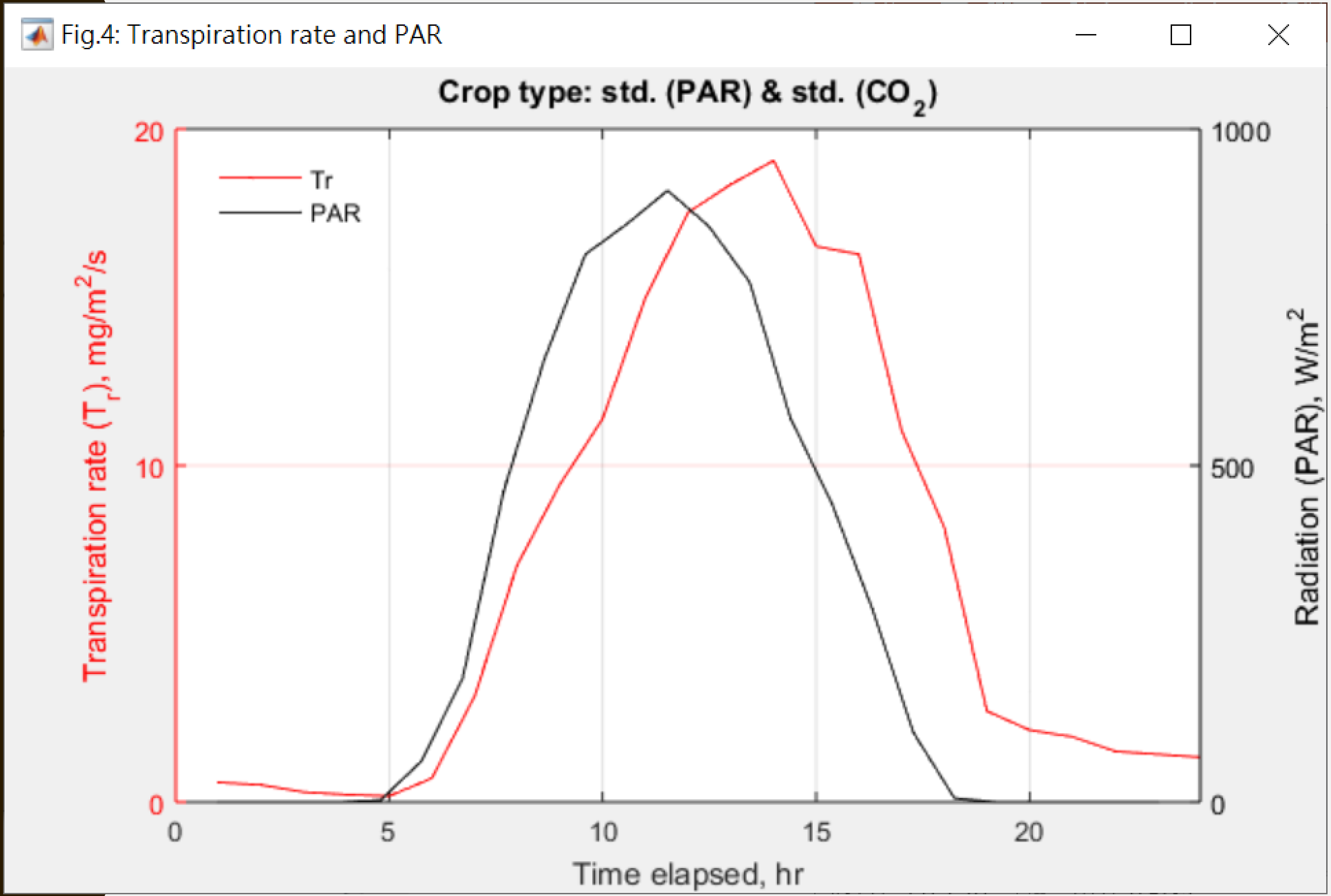
Fig.4: Transpiration rate and PAR
Crop type: std. (PAR) & std. (CO2)
Tr
PAR
20
10
0
1000
500
0
0
5
10
15
20
Time elapsed, hr
Transpiration rate (Tr), mg/m2/s
Radiation (PAR), W/m2

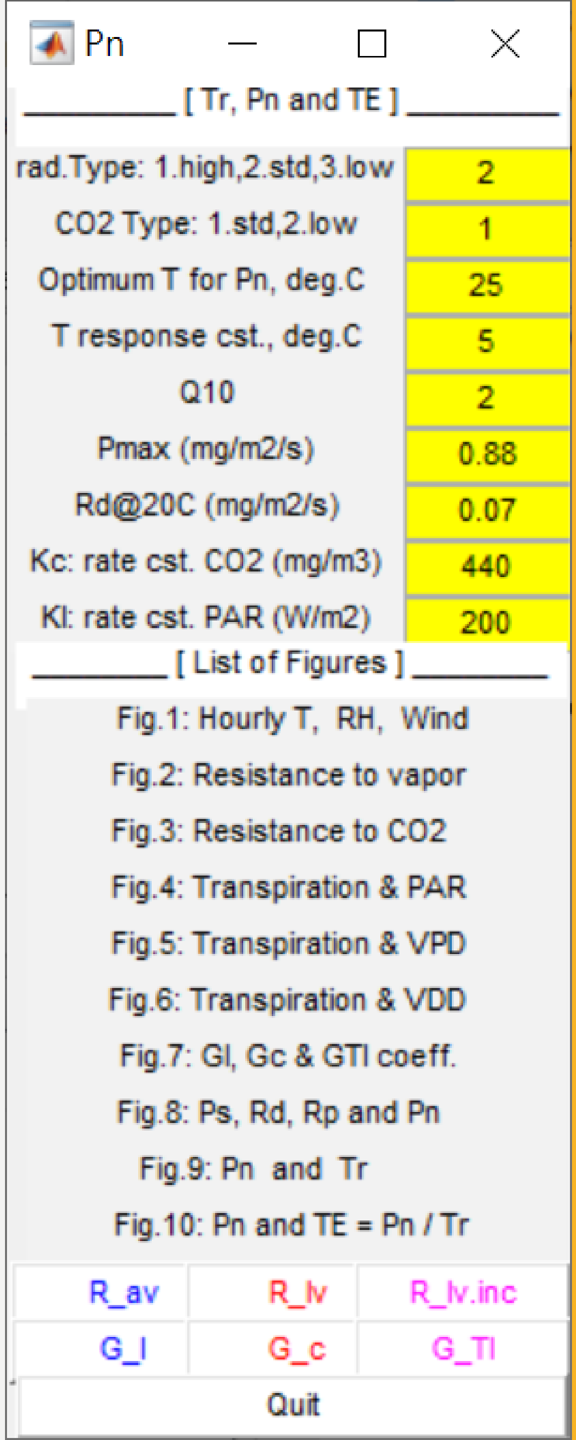
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_TI
Quit

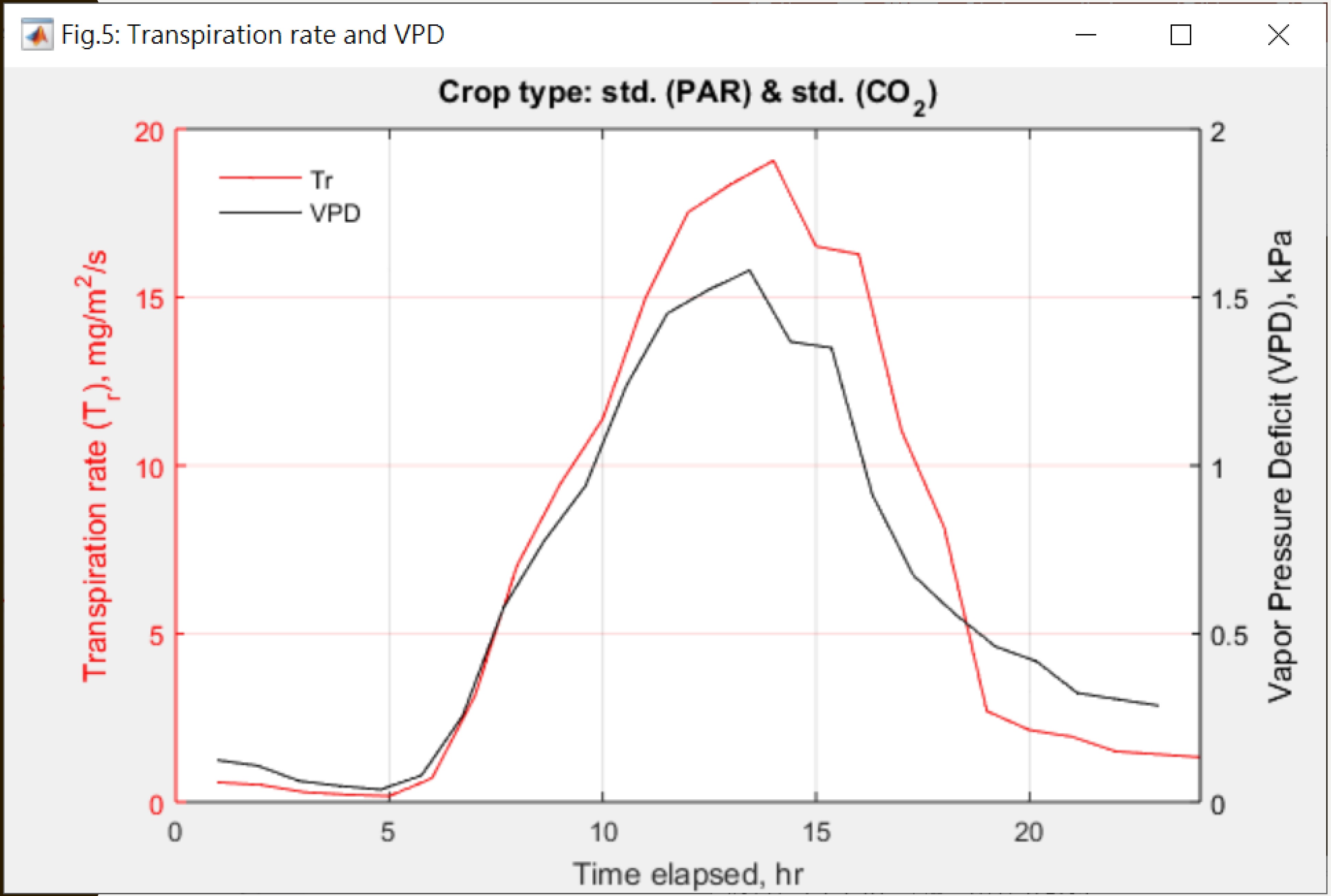
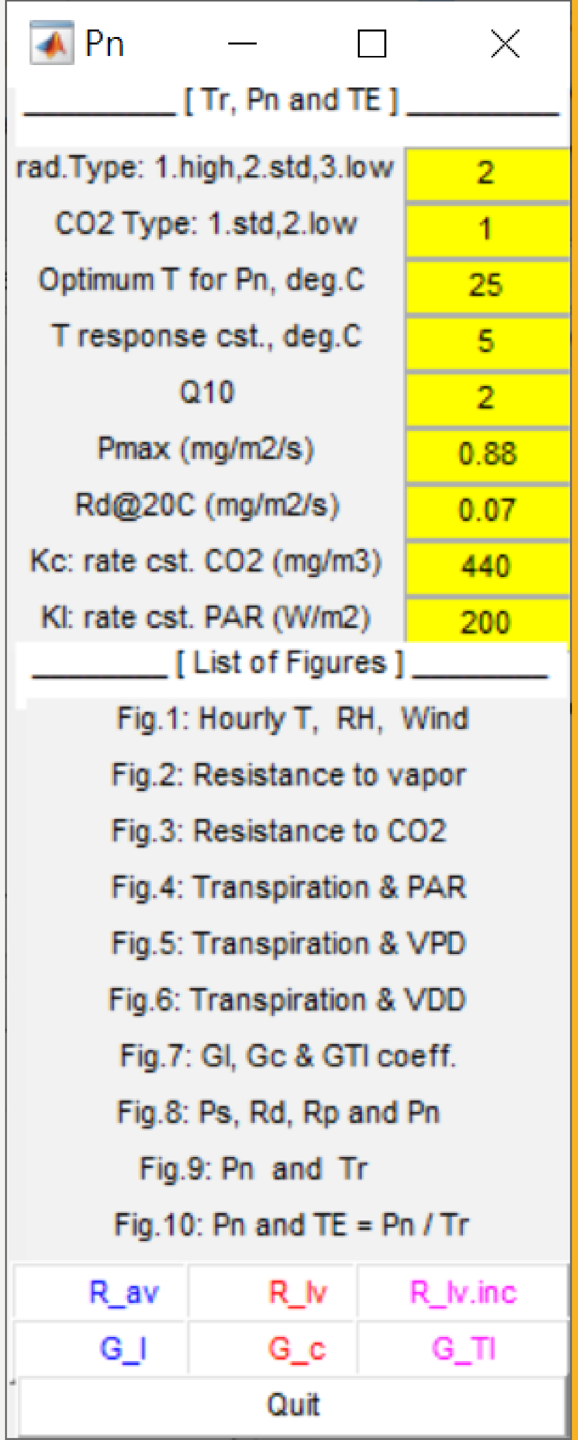


Fig.5: Transpiration rate and VPD
Crop type: std. (PAR) & std. (CO2)
Tr
VPD
Transpiration rate (Tr), mg/m2/s
Vapor Pressure Deficit (VPD), kPa
Time elapsed, hr
0
5
10
15
20
0.5
1
1.5
2


Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

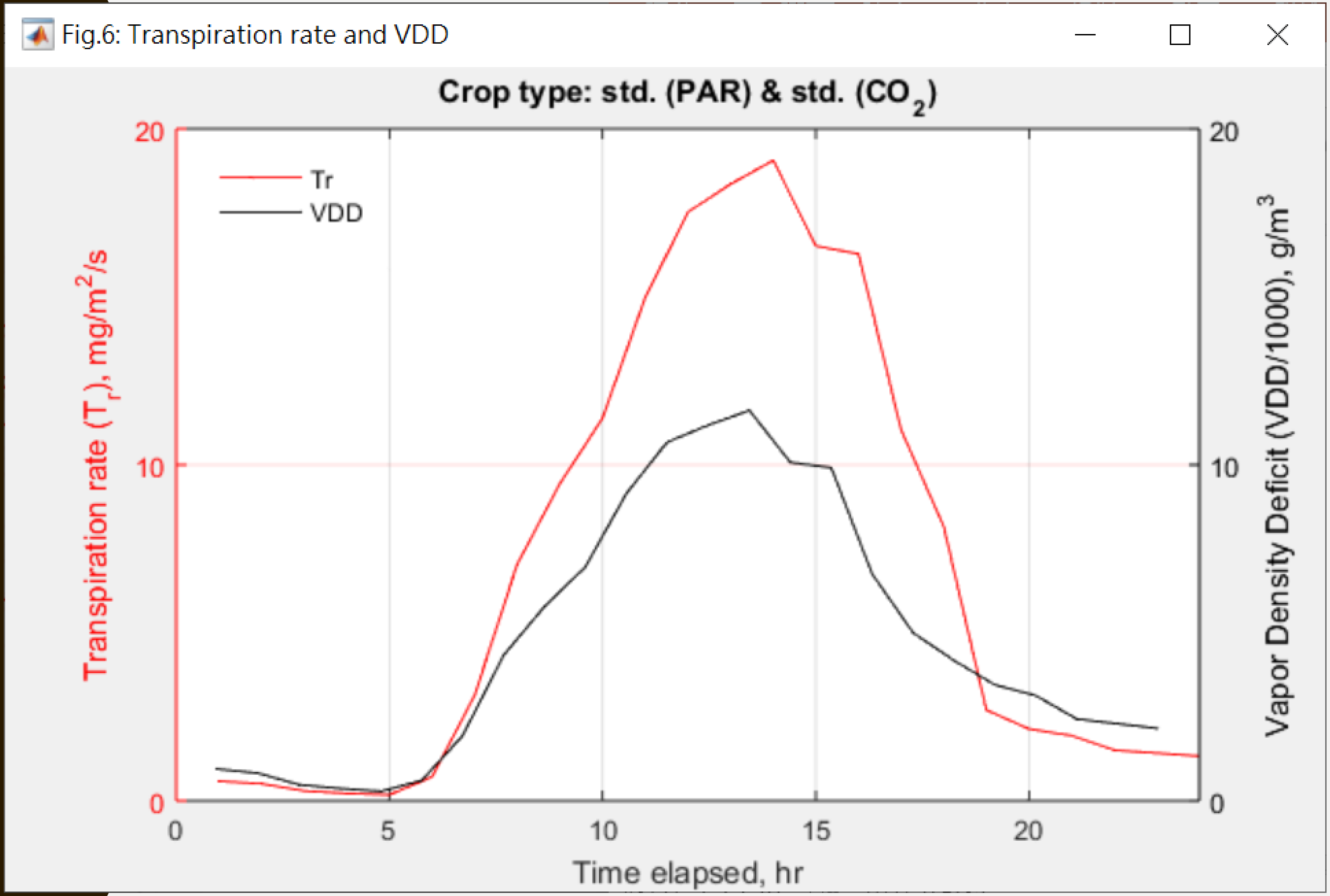
Fig.6: Transpiration rate and VDD
Crop type: std. (PAR) & std. (CO2)
Tr
VDD
Transpiration rate (Tr), mg/m2/s
Vapor Density Deficit (VDD/1000), g/m3
Time elapsed, hr
0
5
10
15
20
10
20

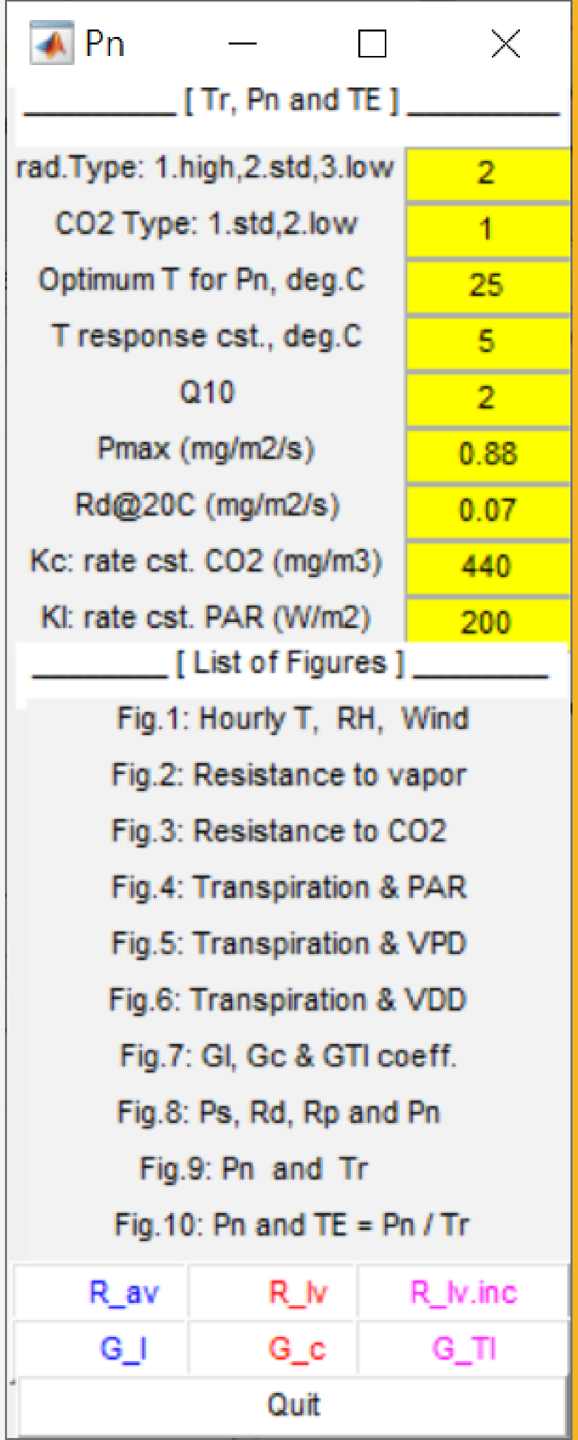
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

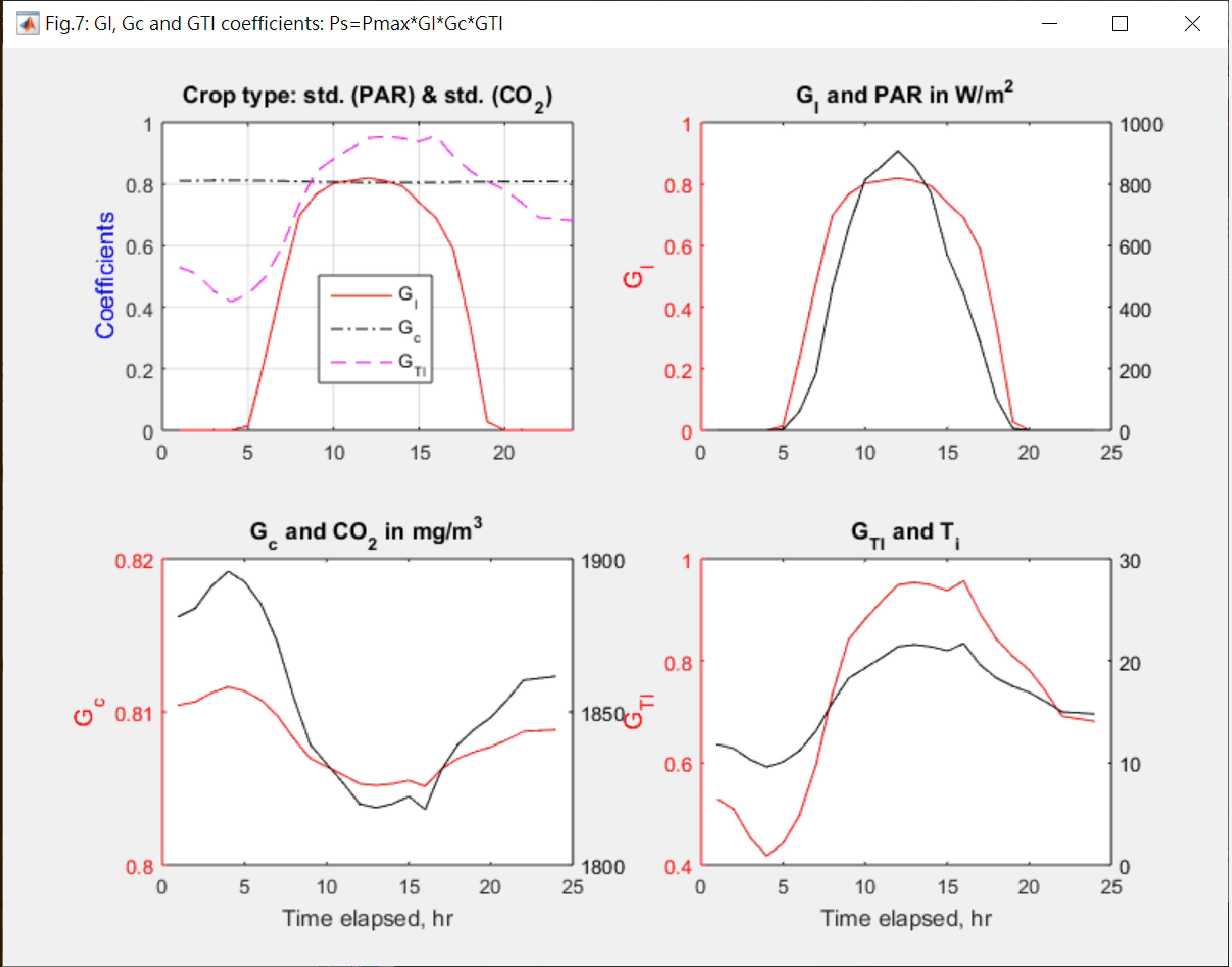


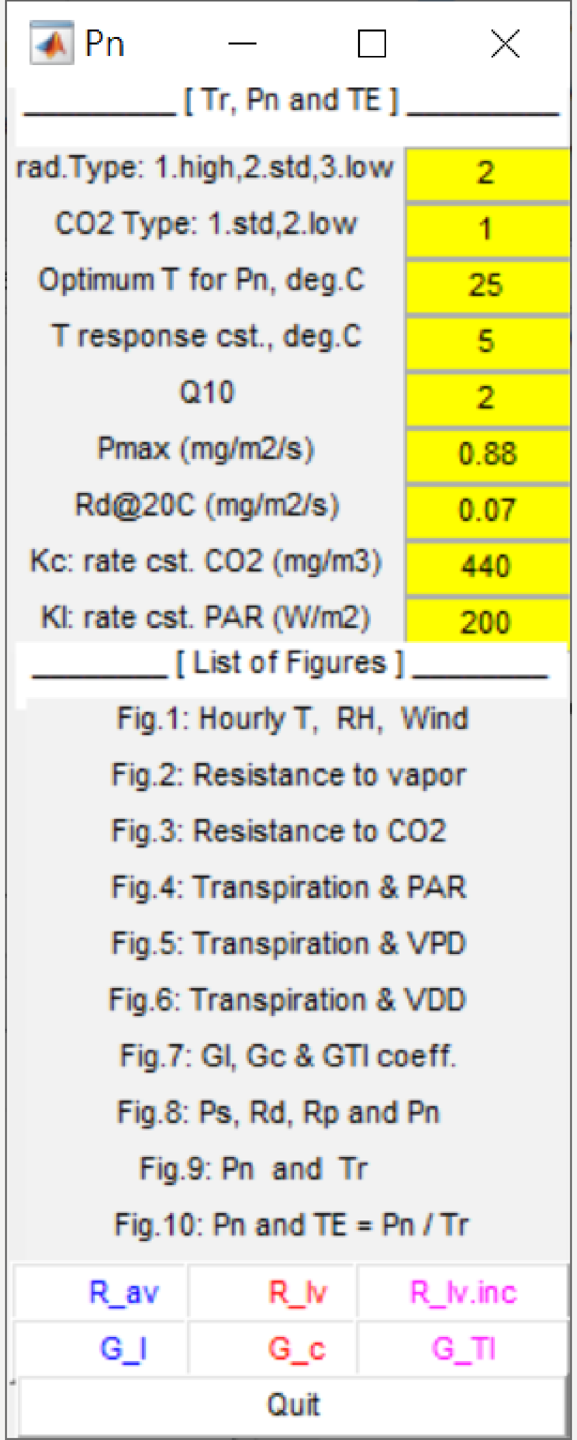
Fig.7: GI, Gc and GTI coefficients: Ps=Pmax*GI*Gc*GTI
Crop type: std. (PAR) & std. (CO2)
Coefficients
GI
Gc
GTI
GI and PAR in W/m2
GI
Gc and CO2 in mg/m3
Gc
GTI and Ti
GTI
Time elapsed, hr
Time elapsed, hr

Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
KI: rate cst. PAR (W/m2)
200
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Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_I
G_c
G_TI
Quit

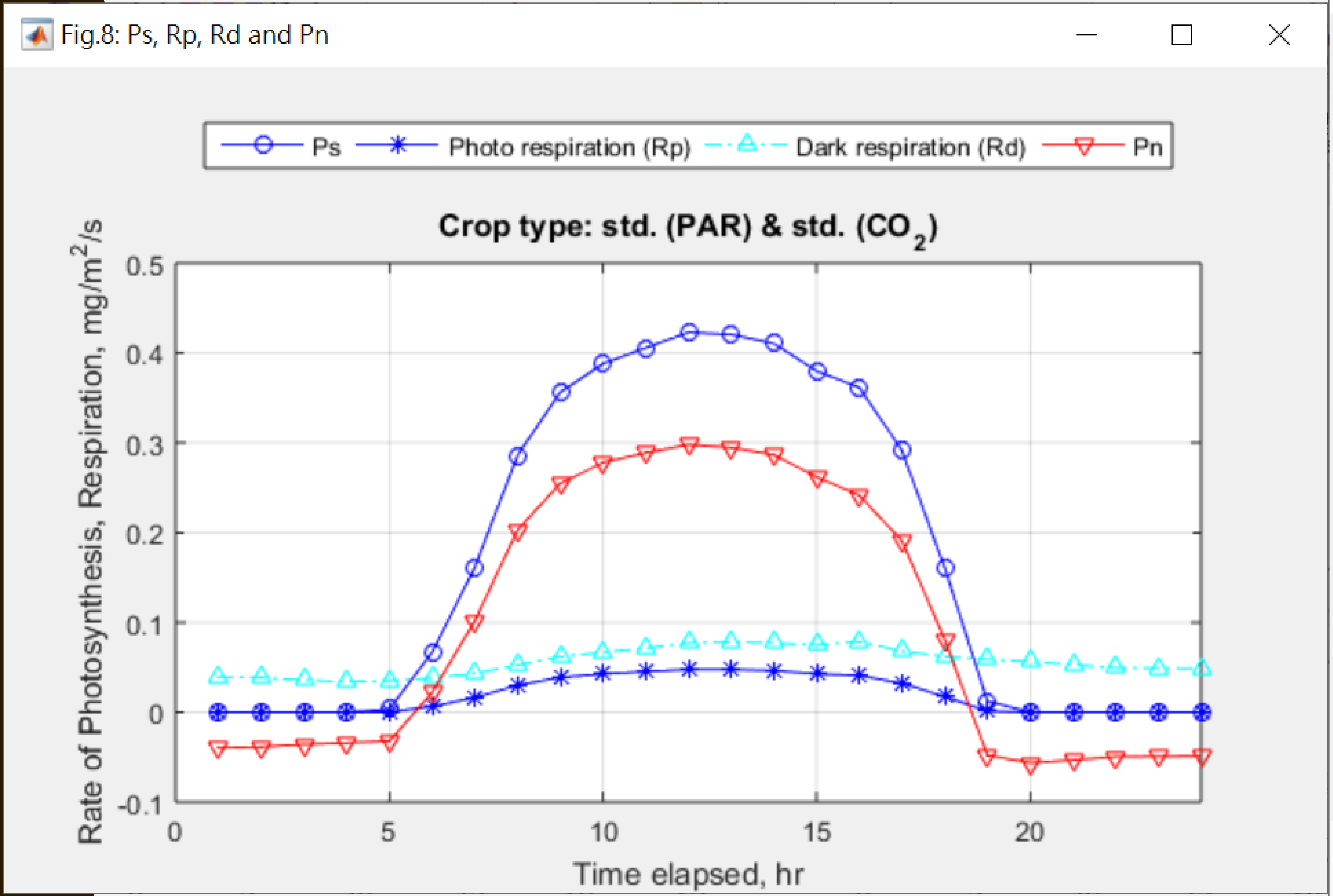
Fig.8: Ps, Rp, Rd and Pn
Ps
Photo respiration (Rp)
Dark respiration (Rd)
Pn
Crop type: std. (PAR) & std. (CO2)
Rate of Photosynthesis, Respiration, mg/m2/s
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
5
10
15
20
Time elapsed, hr

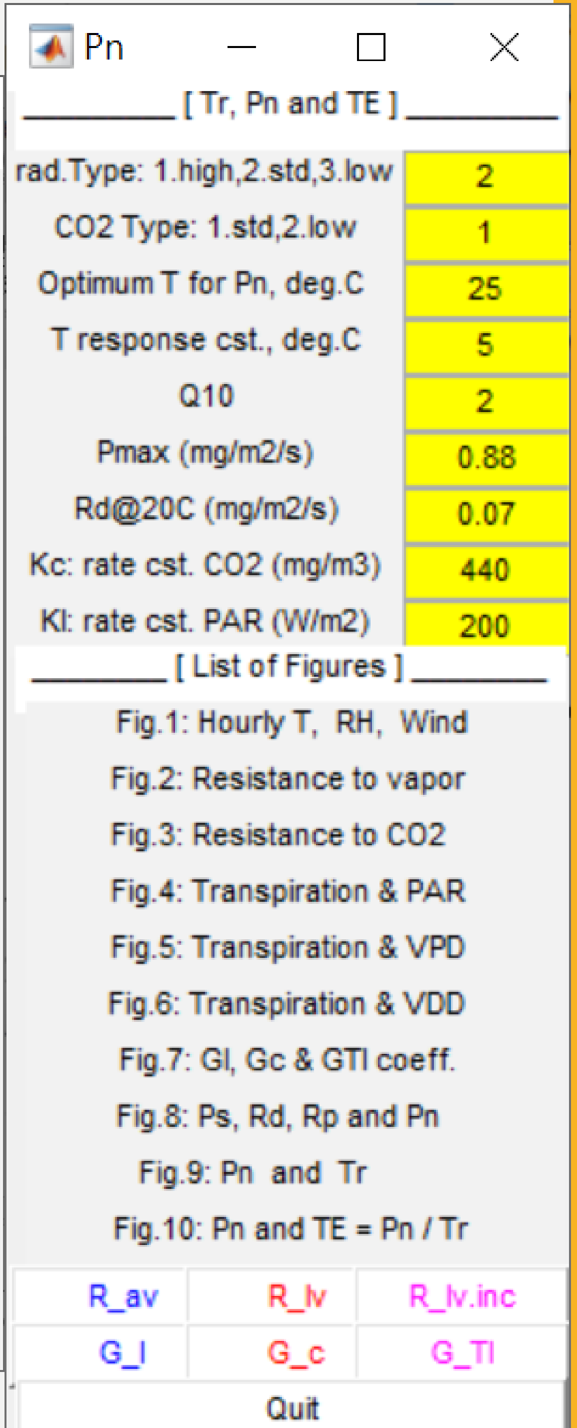
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

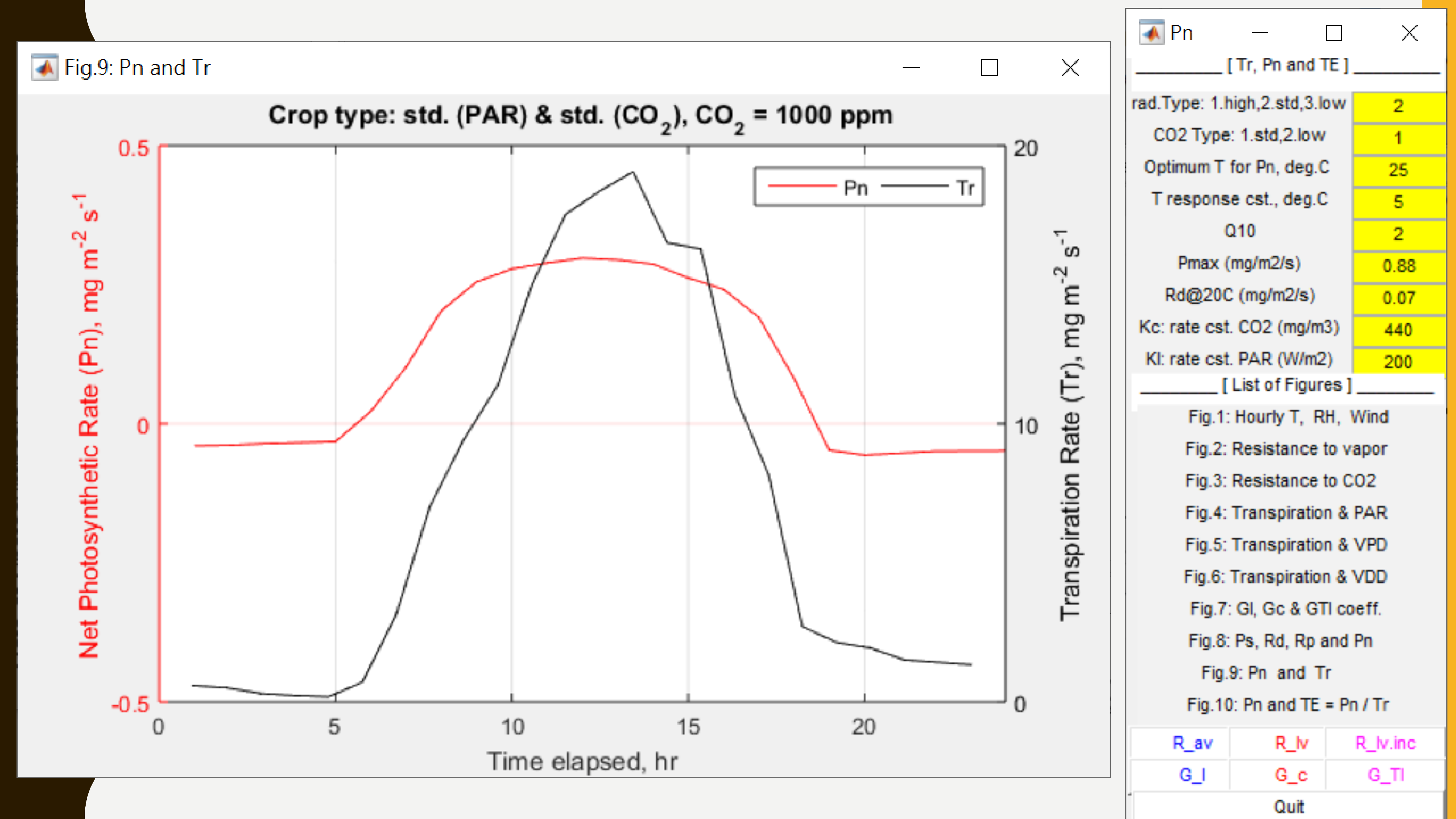
Fig.9: Pn and Tr
Crop type: std. (PAR) & std. (CO2), CO2 = 1000 ppm
Net Photosynthetic Rate (Pn), mg m-2 s-1
Transpiration Rate (Tr), mg m-2 s-1
Time elapsed, hr
Pn
Tr
0.5
0
-0.5
20
10
0
5
15
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.6: Transpiration & VDD
Fig.7: Gl, Gc & GTl coeff.
Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

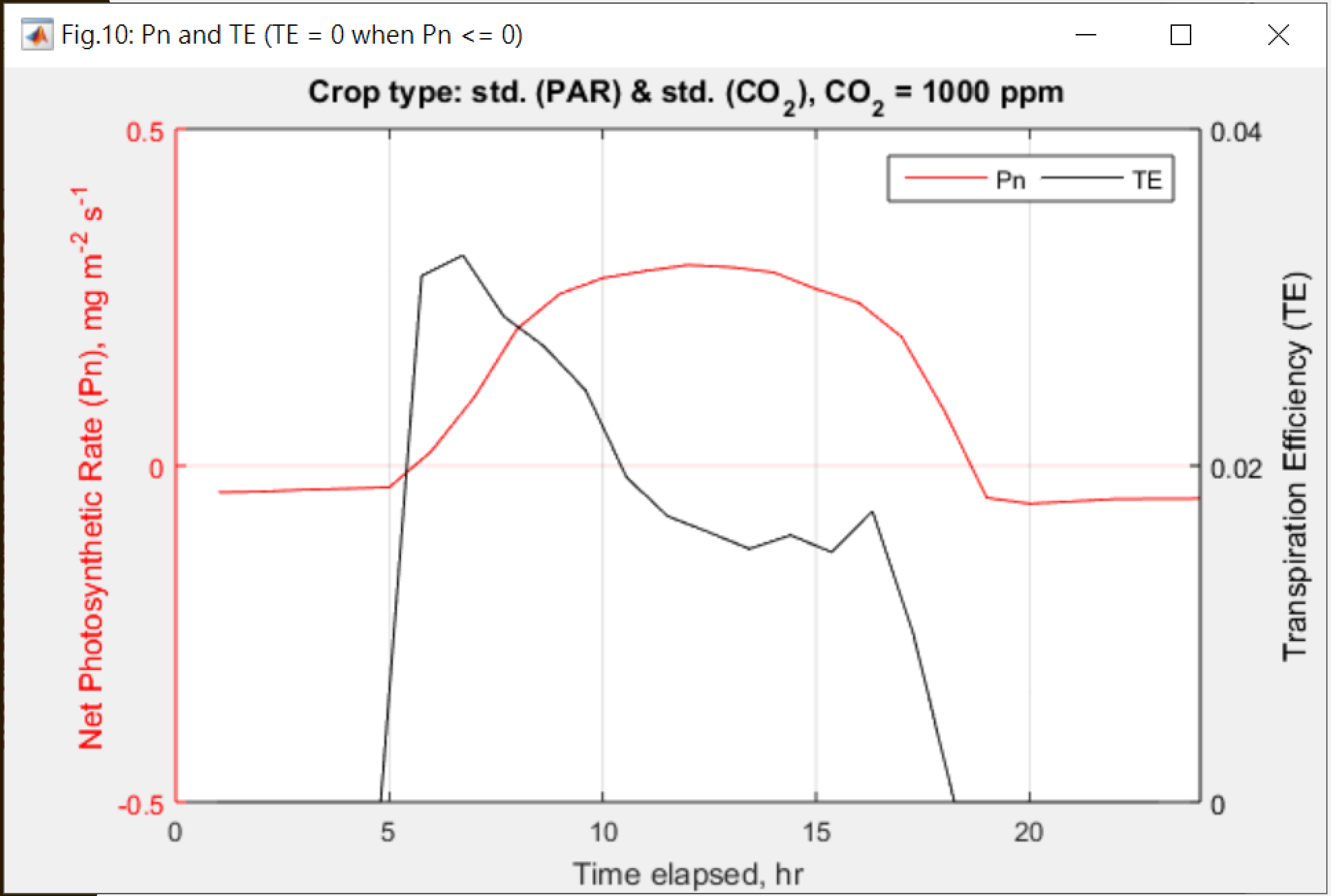
Fig.10: Pn and TE (TE = 0 when Pn <= 0)
Crop type: std. (PAR) & std. (CO2), CO2 = 1000 ppm
Pn
TE
0.5
0
-0.5
0.04
0.02
0
0
5
10
15
20
Net Photosynthetic Rate (Pn), mg m-2 s-1
Transpiration Efficiency (TE)
Time elapsed, hr

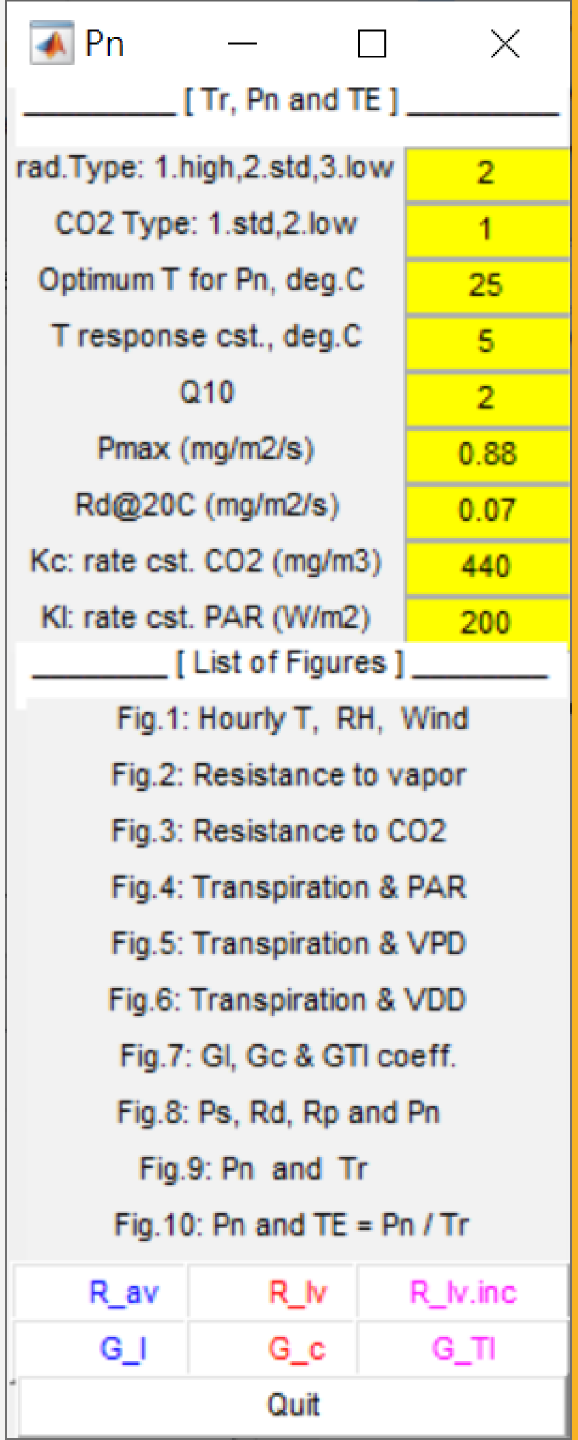
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

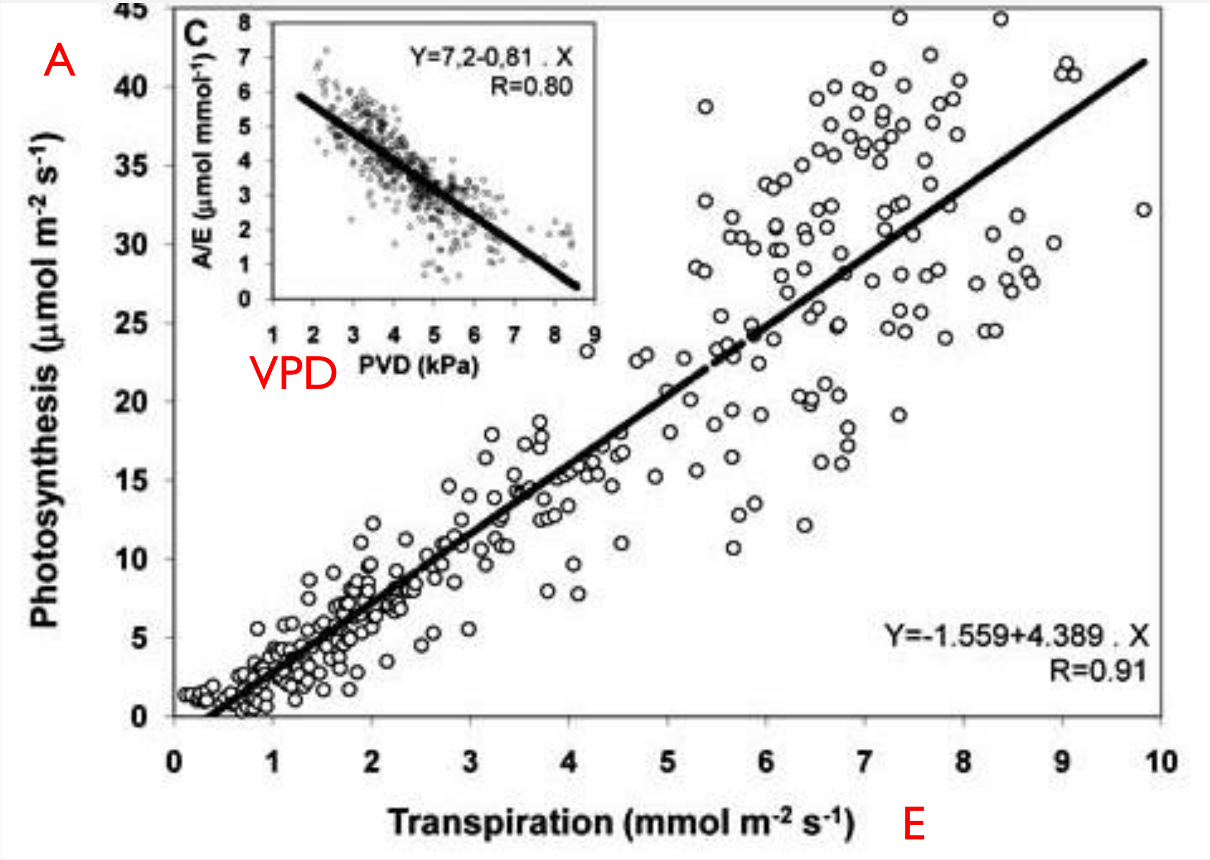
蒸散效率 TRANSPIRATION EFFICIENCY

$$TE = Pn / Tr$$

in (mg CO_2/m^2/s) / (mg Vapor/m^2/s)

當 $Pn \leq 0$ or $Tr = 0$, $TE = 0$

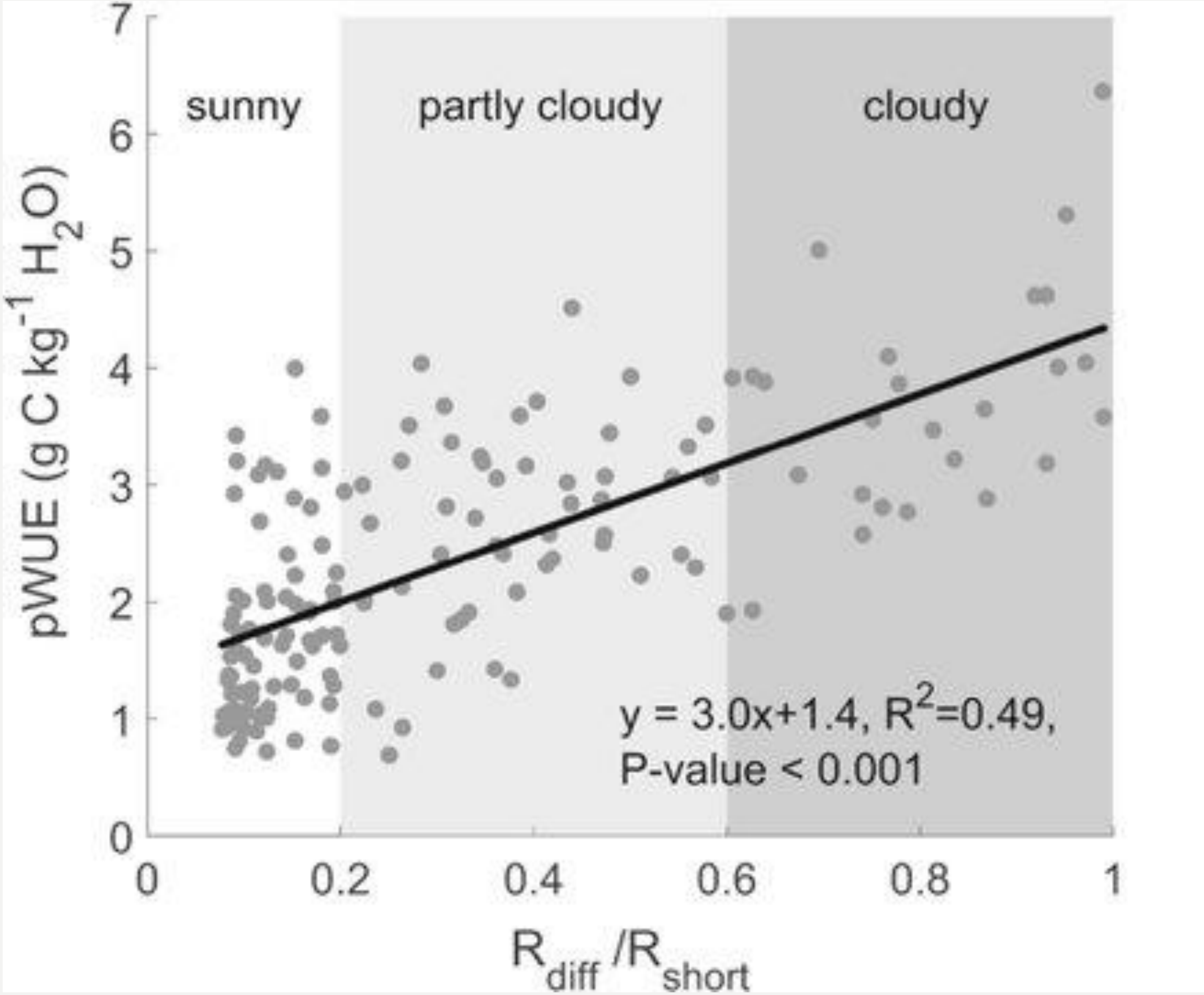
TE: 蒸散效率 = A / E



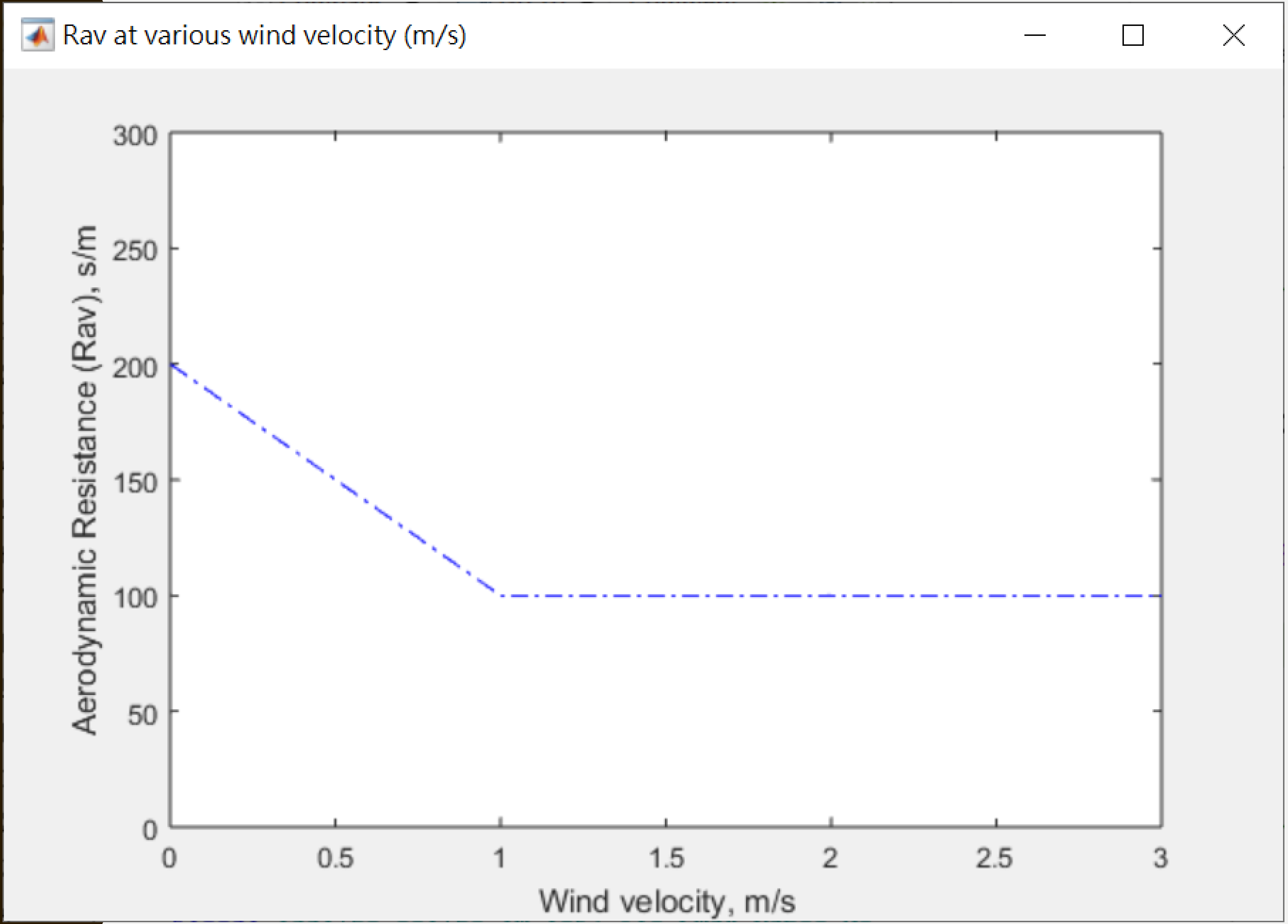
A
VPD
E
C
Y=7,2-0,81 . X
R=0.80
A/E (µmol mmol-1)
PVD (kPa)
Y=-1.559+4.389 . X
R=0.91
Photosynthesis (µmol m-2 s-1)
Transpiration (mmol m-2 s-1)

TE: 蒸散效率

pWUE:
photosynthetic
Water Use Efficiency



Cloudiness is represented by the ratio of diffuse radiation to total shortwave radiation (r = Rdiff/Rshort).


Rav at various wind velocity (m/s)
Aerodynamic Resistance (Rav), s/m
Wind velocity, m/s
0
50
100
150
200
250
300
0
0.5
1
1.5
2
2.5
3

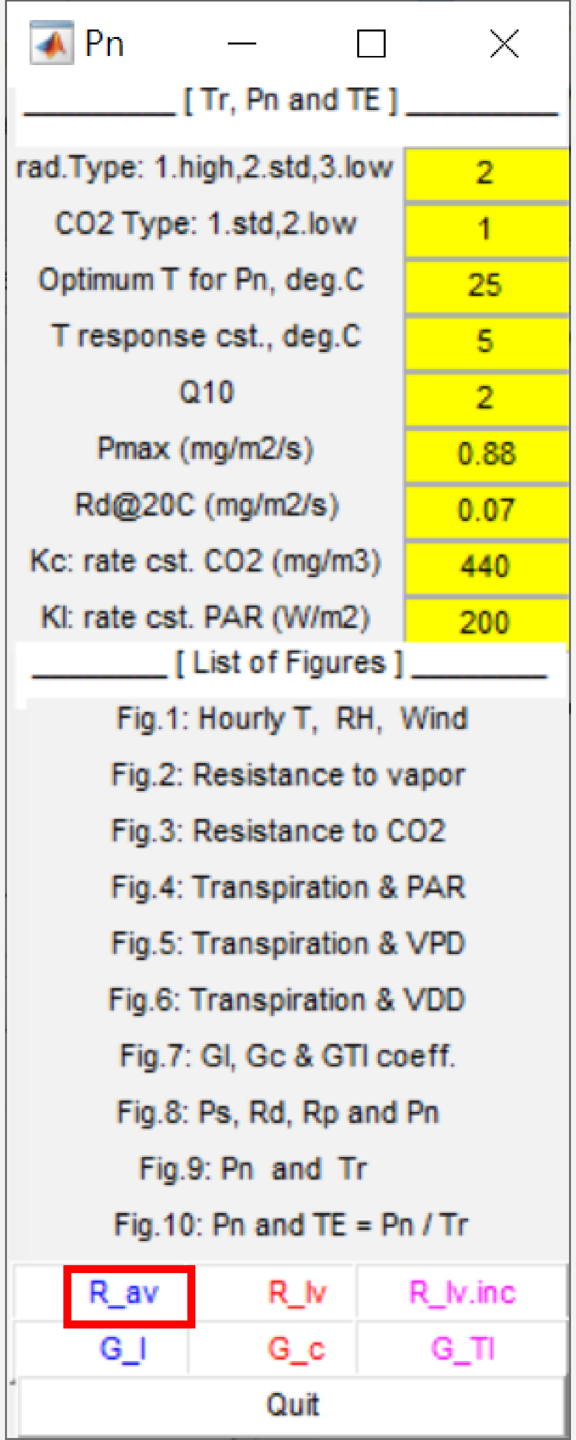

Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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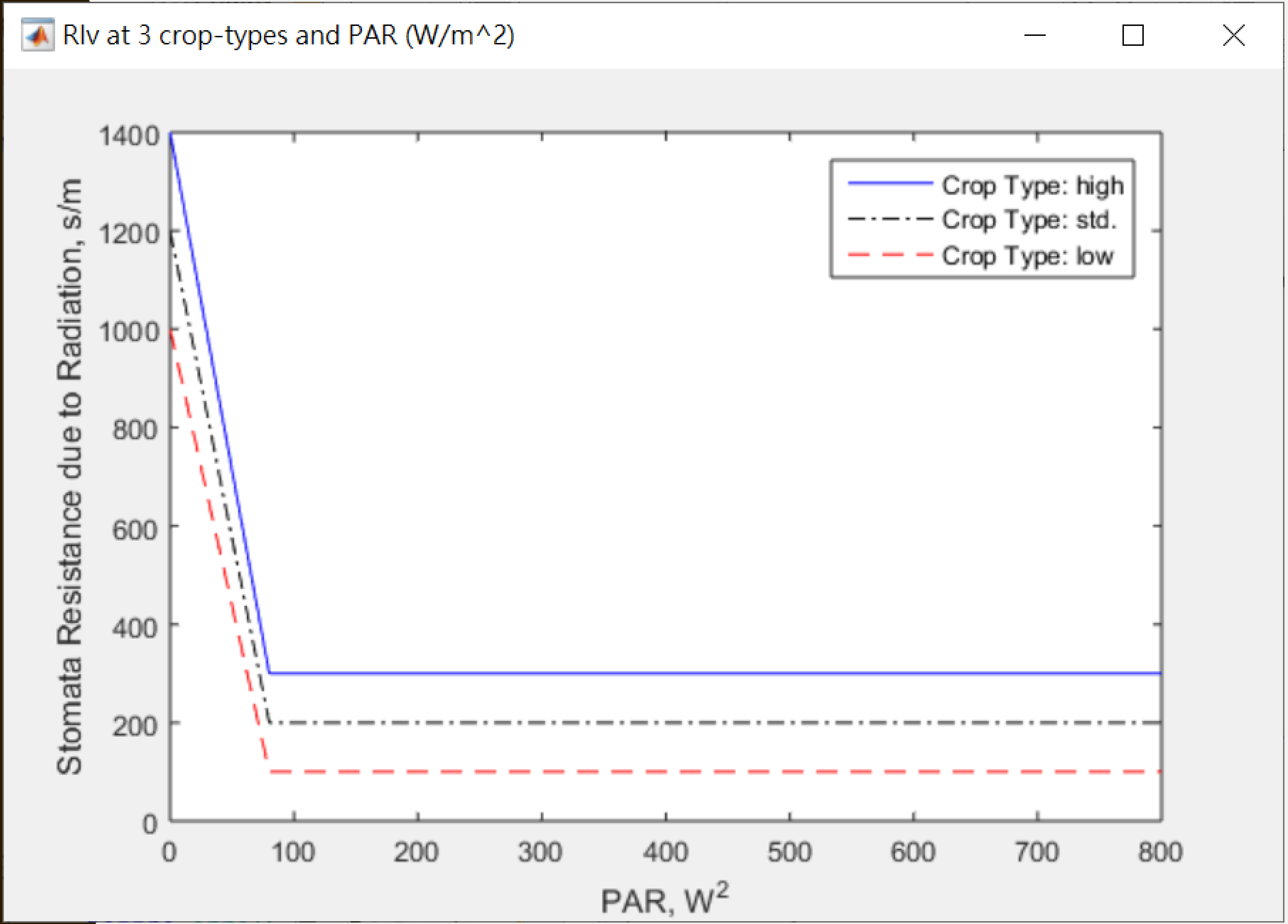
Fig.7: Gl, Gc & GTl coeff.
Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit


Rlv at 3 crop-types and PAR (W/m^2)
Crop Type: high
Crop Type: std.
Crop Type: low
Stomata Resistance due to Radiation, s/m
PAR, W^2
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800

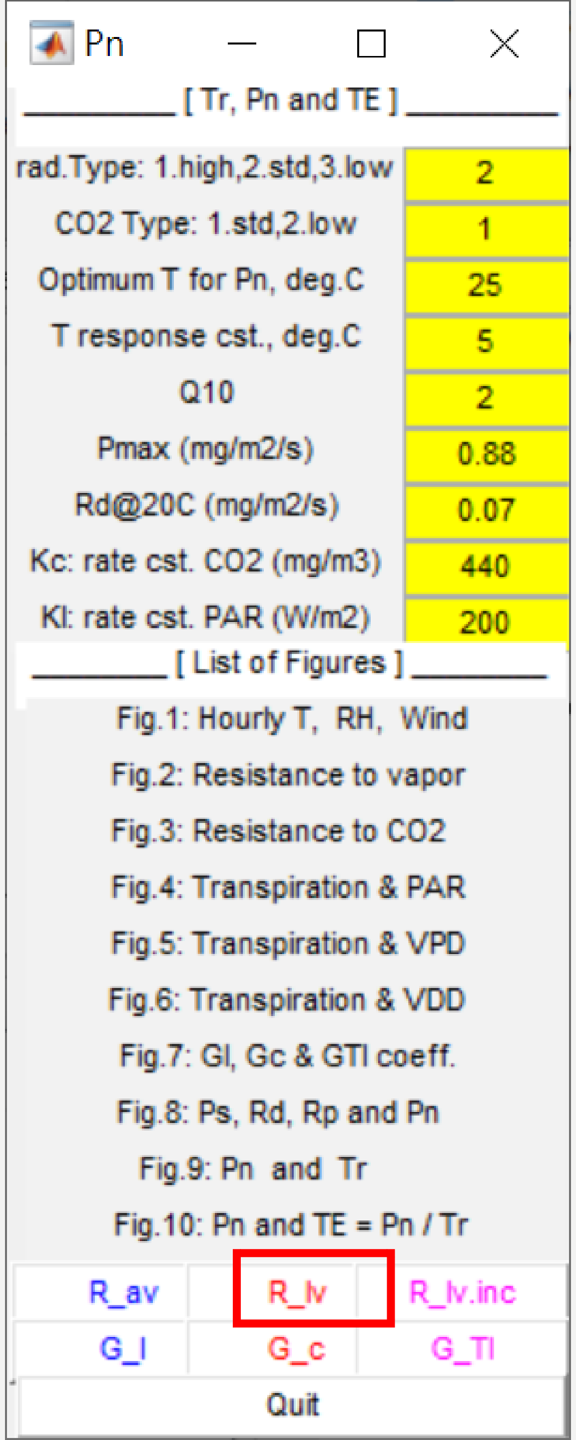

Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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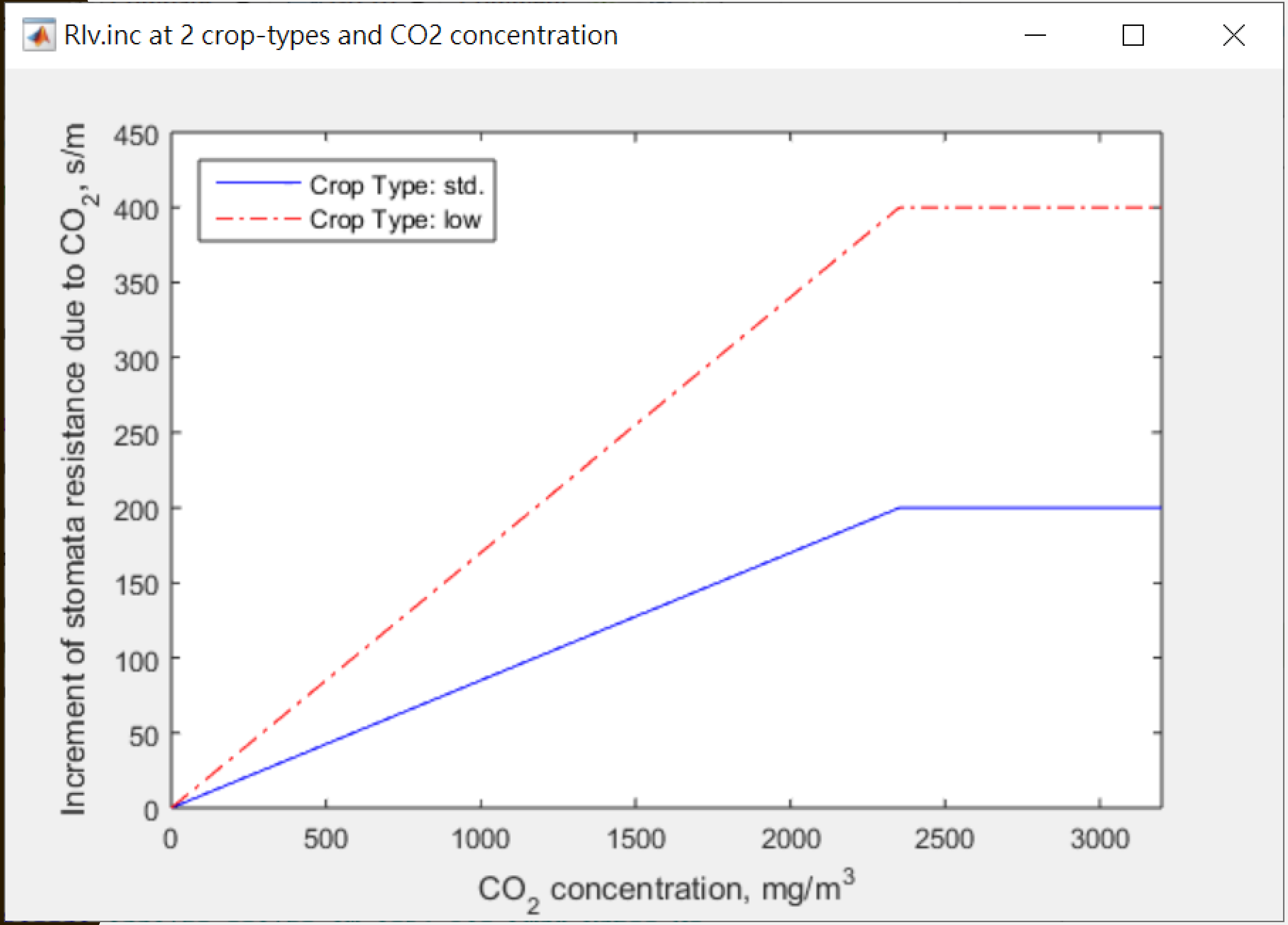
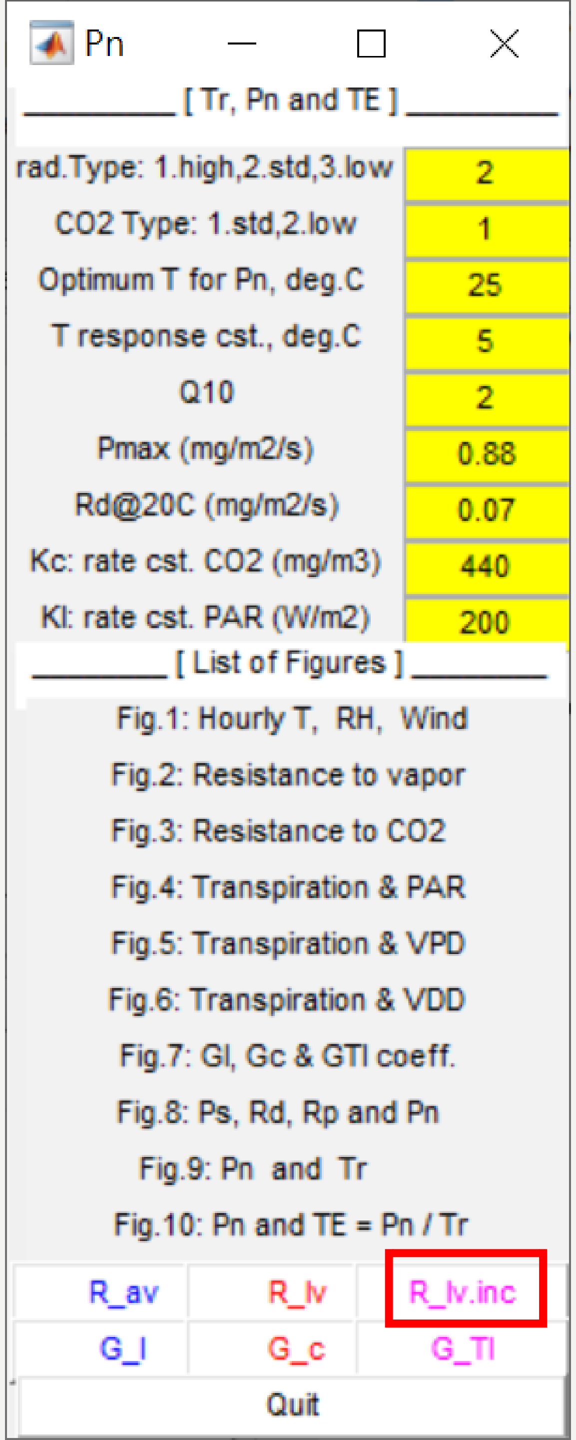
Fig.5: Transpiration & VPD
Fig.6: Transpiration & VDD
Fig.7: Gl, Gc & GTl coeff.
Fig.8: Ps, Rd, Rp and Pn
Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit



Rlv.inc at 2 crop-types and CO2 concentration
Crop Type: std.
Crop Type: low
Increment of stomata resistance due to CO2, s/m
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
CO2 concentration, mg/m3



Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

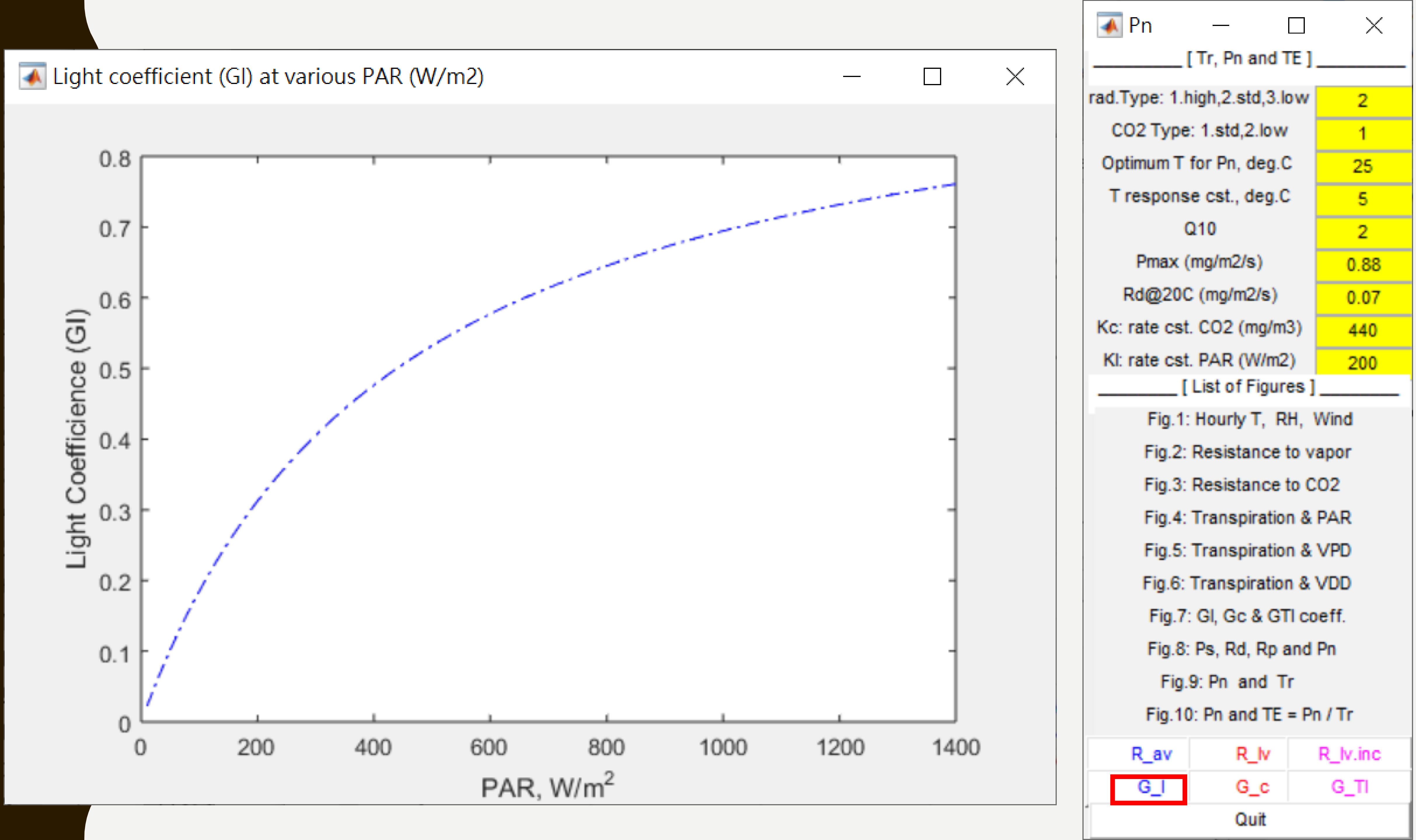
Light coefficient (Gl) at various PAR (W/m2)
Light Coefficience (Gl)
PAR, W/m2
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
0 200 400 600 800 1000 1200 1400
Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low 2
CO2 Type: 1.std,2.low 1
Optimum T for Pn, deg.C 25
T response cst., deg.C 5
Q10 2
Pmax (mg/m2/s) 0.88
Rd@20C (mg/m2/s) 0.07
Kc: rate cst. CO2 (mg/m3) 440
Kl: rate cst. PAR (W/m2) 200
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Fig.6: Transpiration & VDD
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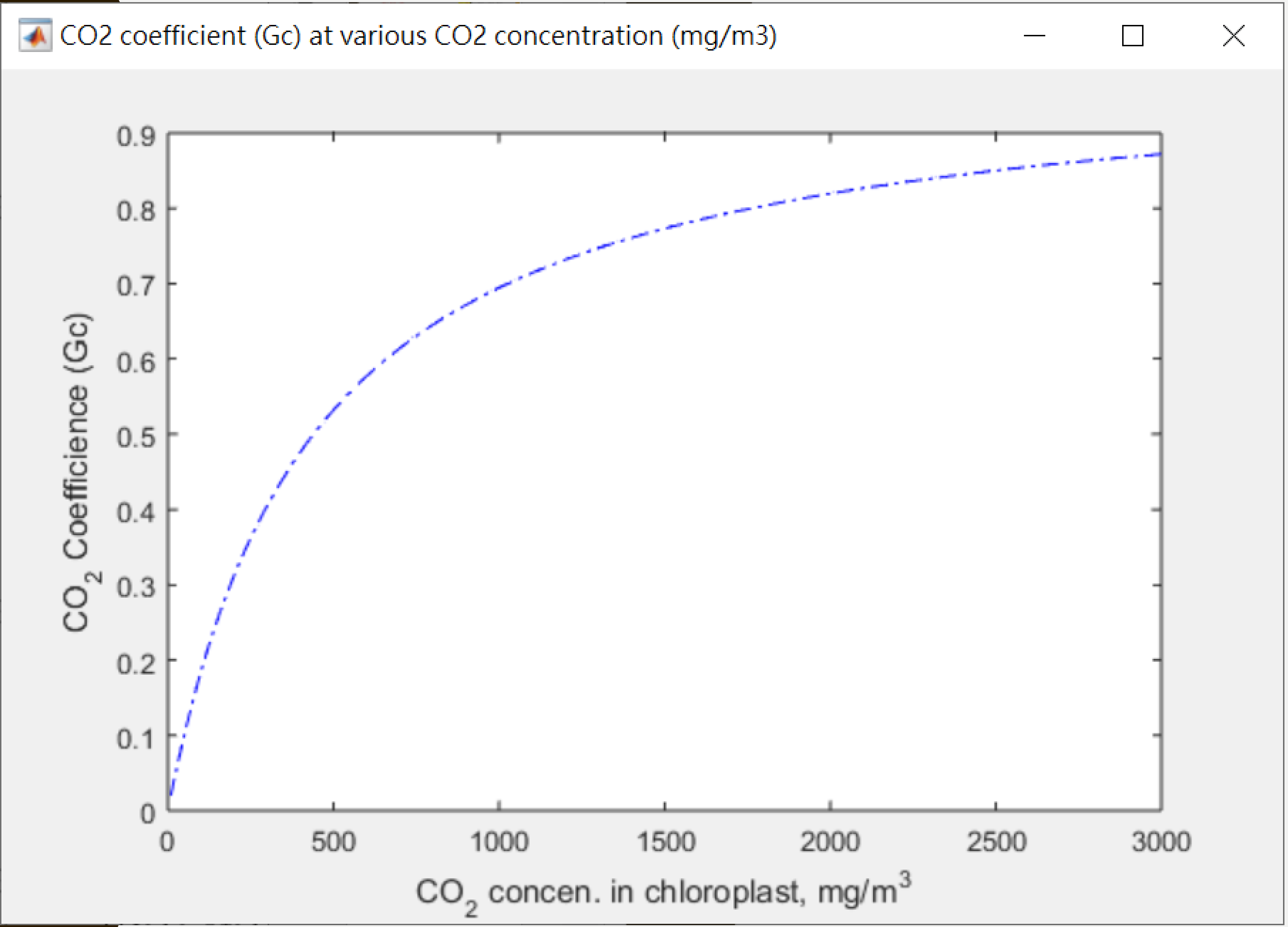
Fig.10: Pn and TE = Pn / Tr
R_av R_lv R_lv.inc
G_l G_c G_Tl
Quit


CO2 coefficient (Gc) at various CO2 concentration (mg/m3)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000
CO2 Coefficience (Gc)
CO2 concen. in chloroplast, mg/m3

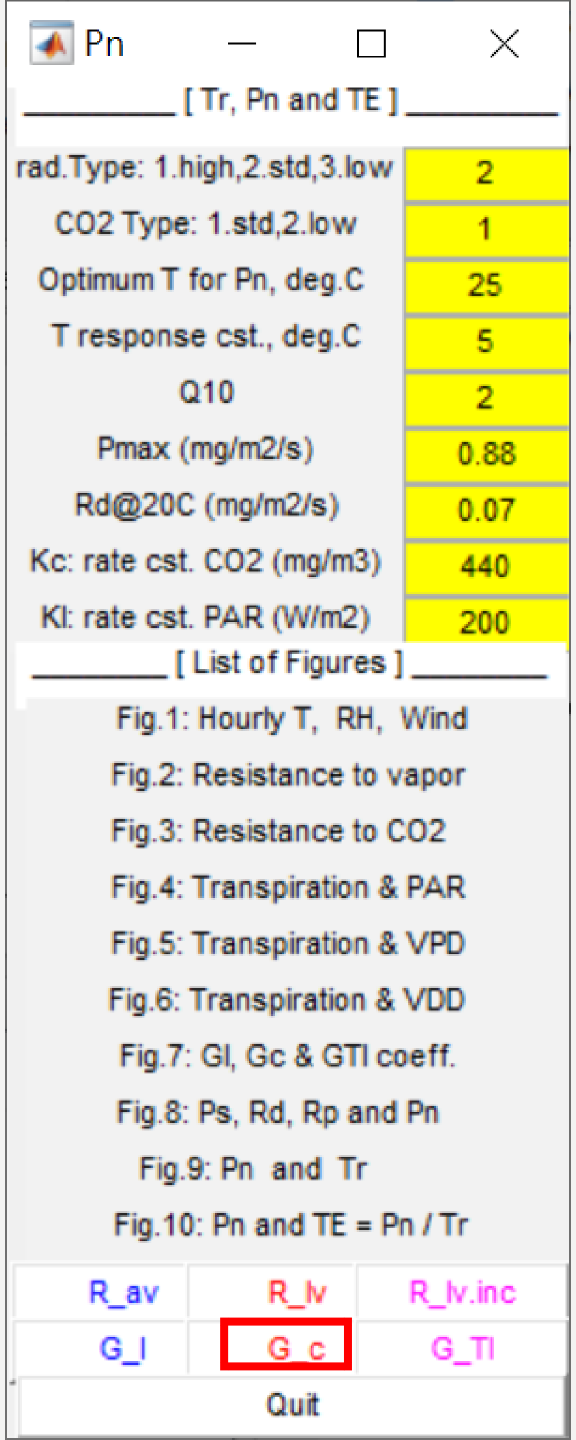

Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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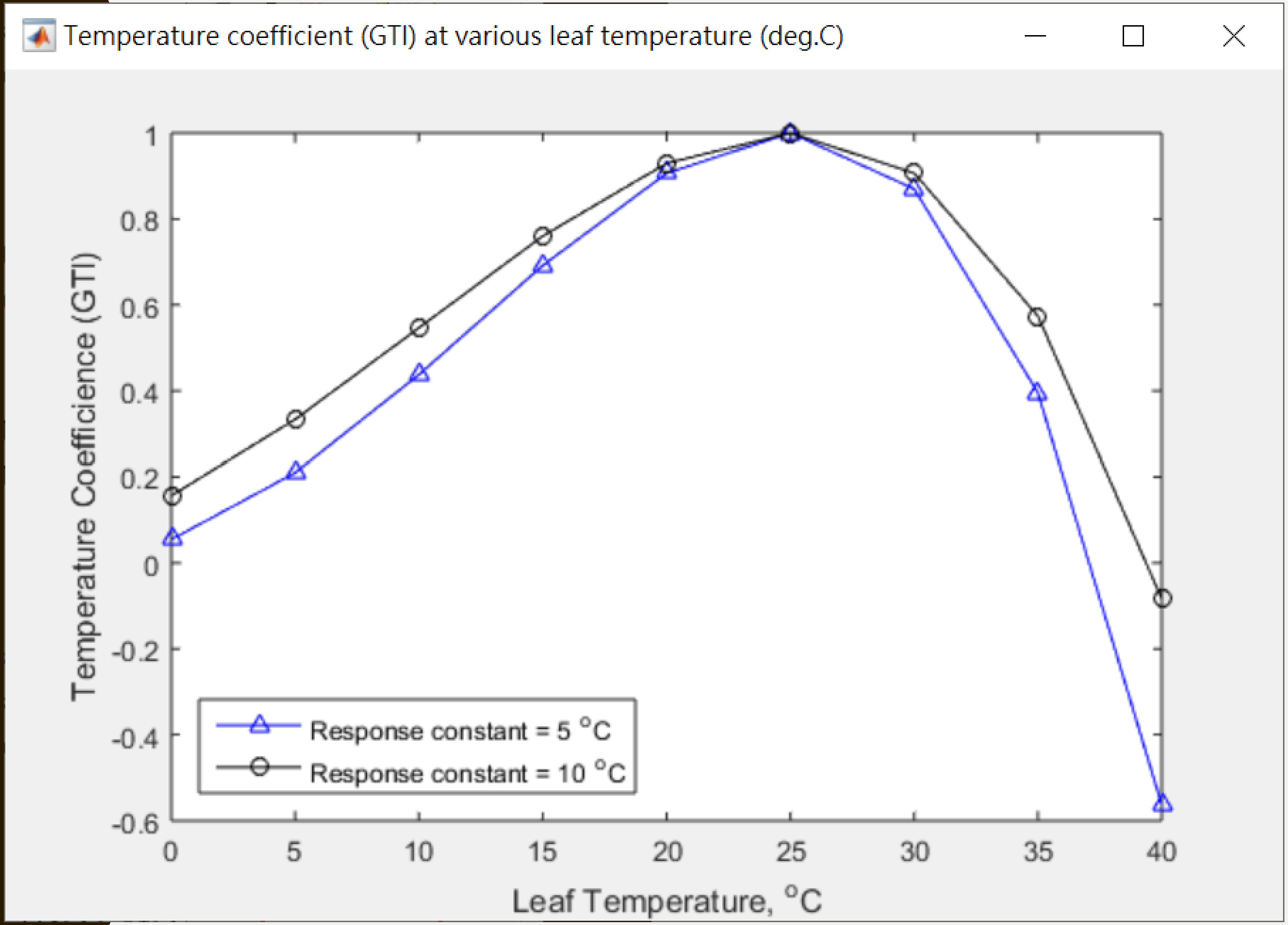
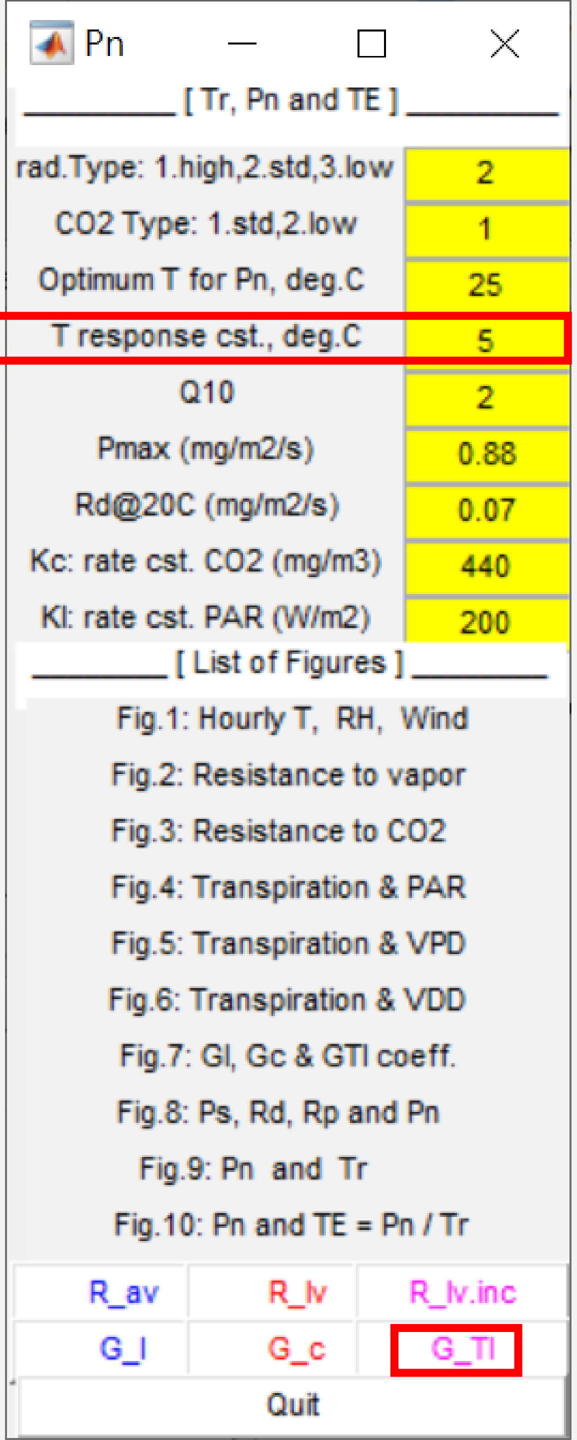
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit



Temperature coefficient (GTI) at various leaf temperature (deg.C)
Temperature Coefficience (GTI)
Leaf Temperature, °C
Response constant = 5 °C
Response constant = 10 °C
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
5
10
15
20
25
30
35
40



Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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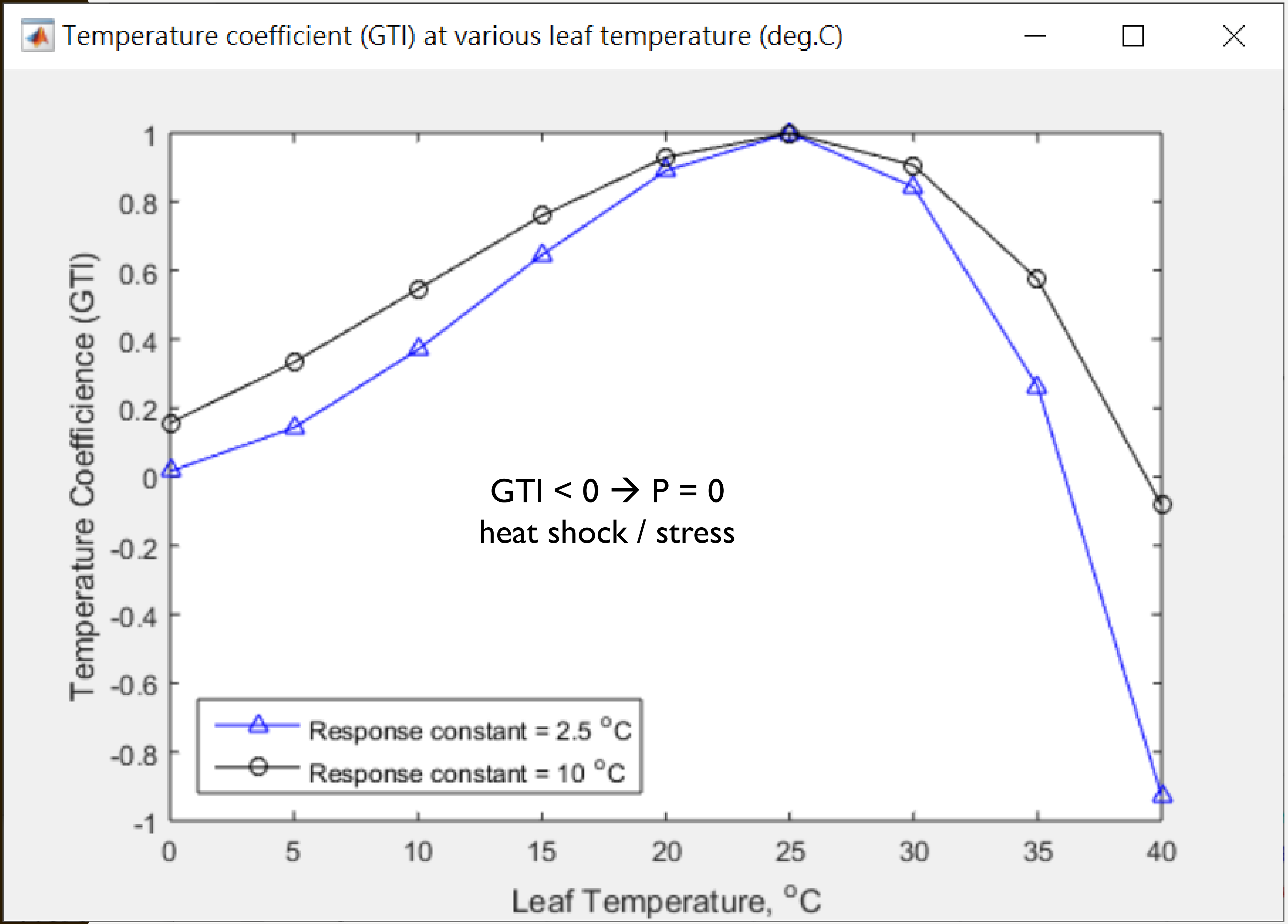
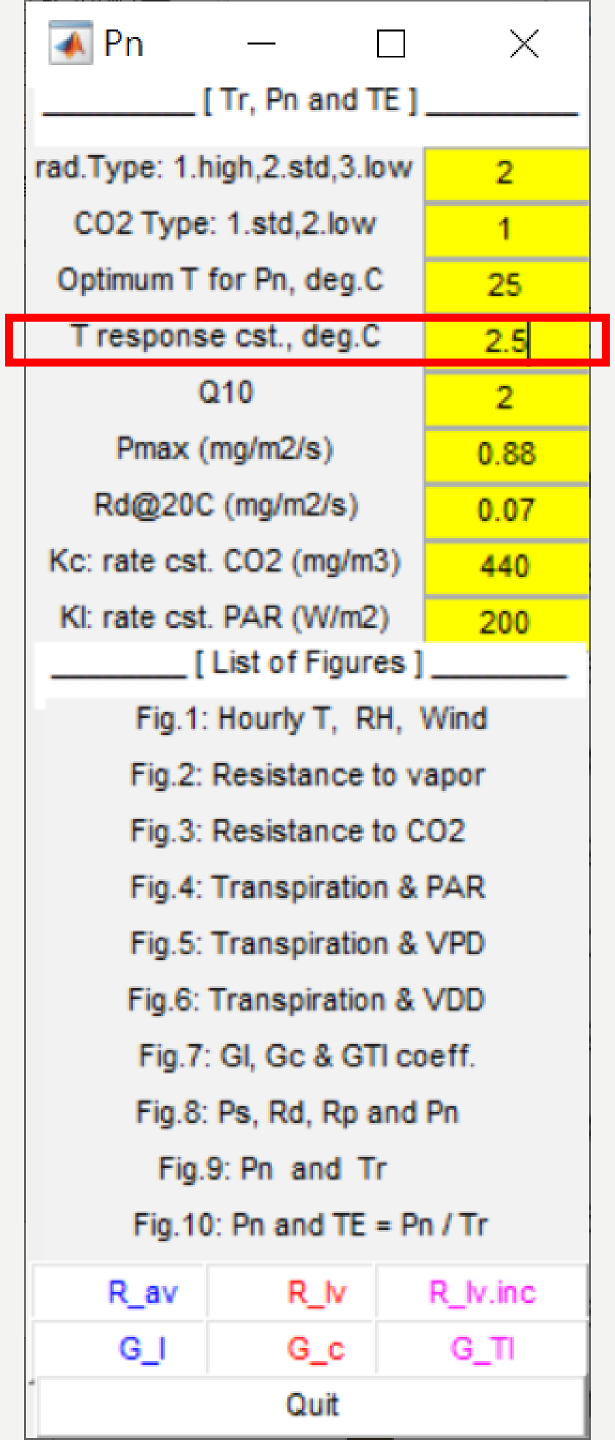
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit



Temperature coefficient (GTI) at various leaf temperature (deg.C)
Temperature Coefficience (GTI)
Leaf Temperature, °C
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
5
10
15
20
25
30
35
40
Response constant = 2.5 °C
Response constant = 10 °C
GTI < 0 → P = 0
heat shock / stress



Pn
[Tr, Pn and TE]
rad.Type: 1.high,2.std,3.low
2
CO2 Type: 1.std,2.low
1
Optimum T for Pn, deg.C
25
T response cst., deg.C
2.5
Q10
2
Pmax (mg/m2/s)
0.88
Rd@20C (mg/m2/s)
0.07
Kc: rate cst. CO2 (mg/m3)
440
Kl: rate cst. PAR (W/m2)
200
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Fig.9: Pn and Tr
Fig.10: Pn and TE = Pn / Tr
R_av
R_lv
R_lv.inc
G_l
G_c
G_Tl
Quit

Pn Simulation.xlsx

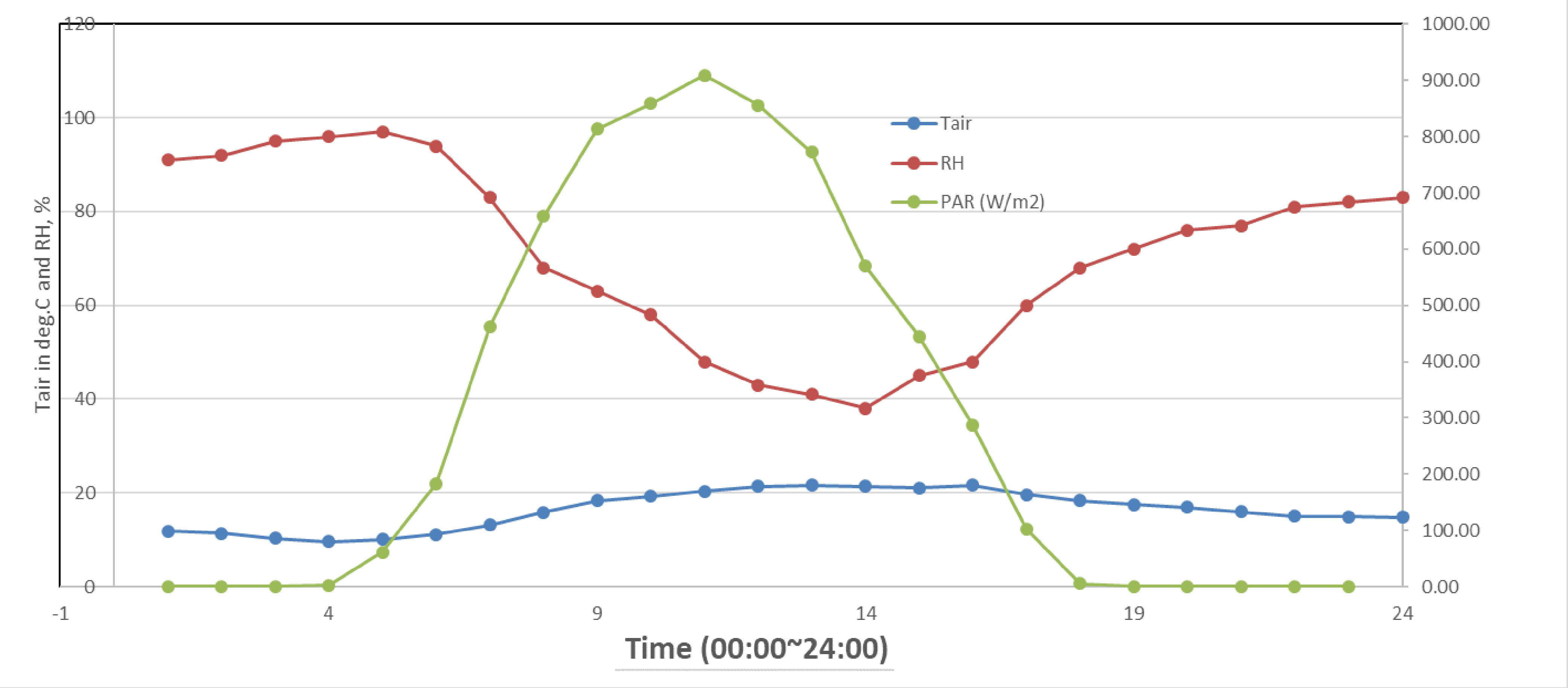
淨光合速率

NET PHOTOSYNTHETIC RATE

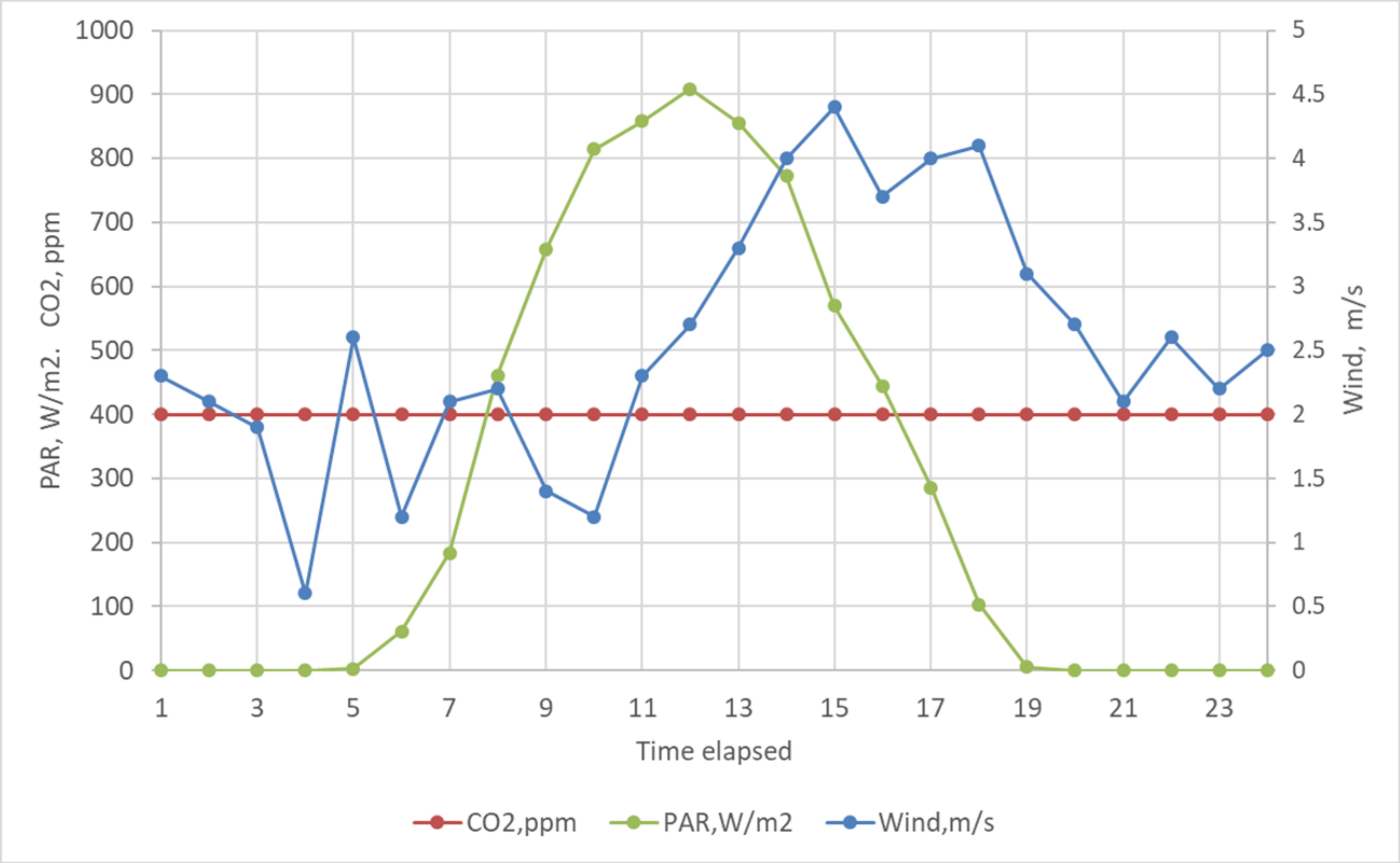
$mg\ m^{-2}\ s^{-1}$

$\mu mol\ m^{-2}\ s^{-1}$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Assumpti		Pma	3.123136		Q10=	2	Rd(20C)=	0.07		Kc=	440							PhotoResp/Ph	Dark Respira
2	hr:mn	T,°C	RH,%	Wind,m/s	PAR,MJ/m	CO2,ppm	PAR,W/m2	CO2,mg/m	Vps,g/m3	Vds, g/m3	Vd,g/m3	Rlv, s/m	Rav,s/m	Rlv.inc,s/m	Tr,mg/(m3.s	GI	Gc	GTI	Kpr	Rd,mg/(m3.s
3	1	11.8	91	2.3	0	400	0.00	784	1.38	10.52	9.57	1200	100	133	0.66	0	0.6405	0.5289	0.3333	0.0397
4	2	11.4	92	2.1	0	400	0.00	784	1.35	10.26	9.44	1200	100	133	0.57	0	0.6405	0.5084	0.3333	0.0386
5	3	10.3	95	1.9	0	400	0.00	784	1.25	9.57	9.09	1200	100	133	0.33	0	0.6405	0.4525	0.3333	0.0357
6	4	9.6	96	0.6	0	400	0.00	784	1.20	9.16	8.79	1200	140	133	0.25	0	0.6405	0.4176	0.3333	0.0340
7	5	10																		0.0352
8	6	11																		0.0380
9	7	13																		0.0434
10	8	15																		0.0527
11	9	18																		0.0622
12	10	19																		0.0667
13	11	20																		0.0715
14	12	21																		0.0771
15	13	21																		0.0782
16	14	21																		0.0771
17	15	2																		0.0750
18	16	21																		0.0788
19	17	19																		0.0681
20	18	18																		0.0622
21	19	17																		0.0589
22	20	16																		0.0565
23	21	1																		0.0531
24	22	1																		0.0495
25	23	14																		0.0492
26	24	14																		0.0488
27																				



溫室內24小時的逐時輻射能、二氧化碳與風速



計算水汽進出氣孔的阻力與蒸散速率

- 風速、作物種類、光量、CO_2濃度
- $R_{v.total} = R_{av} + R_{lv} + R_{lv.inc}$

due to Wind	1	due to light	low	std	high
Rav	100		Rlv	Rlv	Rlv
			100	200	300

Rv.total=424.5 for std., light and std. CO_2 condition

assuming RH=40%		VD_40%RH	6.91		
assuming Tl=Tair		VD_100%RH	17.27	Vps	2.34
as shown in Chap.7		VDD=	10.36	g/m3	
			10364.63	mg/m3	
			low	std	high due to light
Tr=VDD/Rv	in g/m3*m/s	Due to CO_2 std.	31.94	24.42	19.76
	=g/m2/s	Due to CO_2 low	39.52	28.61	22.42

	Rlv.inc.	Rv=sum of Rav, Rlv, Rlv.inc, in s/m		
std	124.51	324.5	424.5	524.5
low	62.25	262.25	362.25	462.25

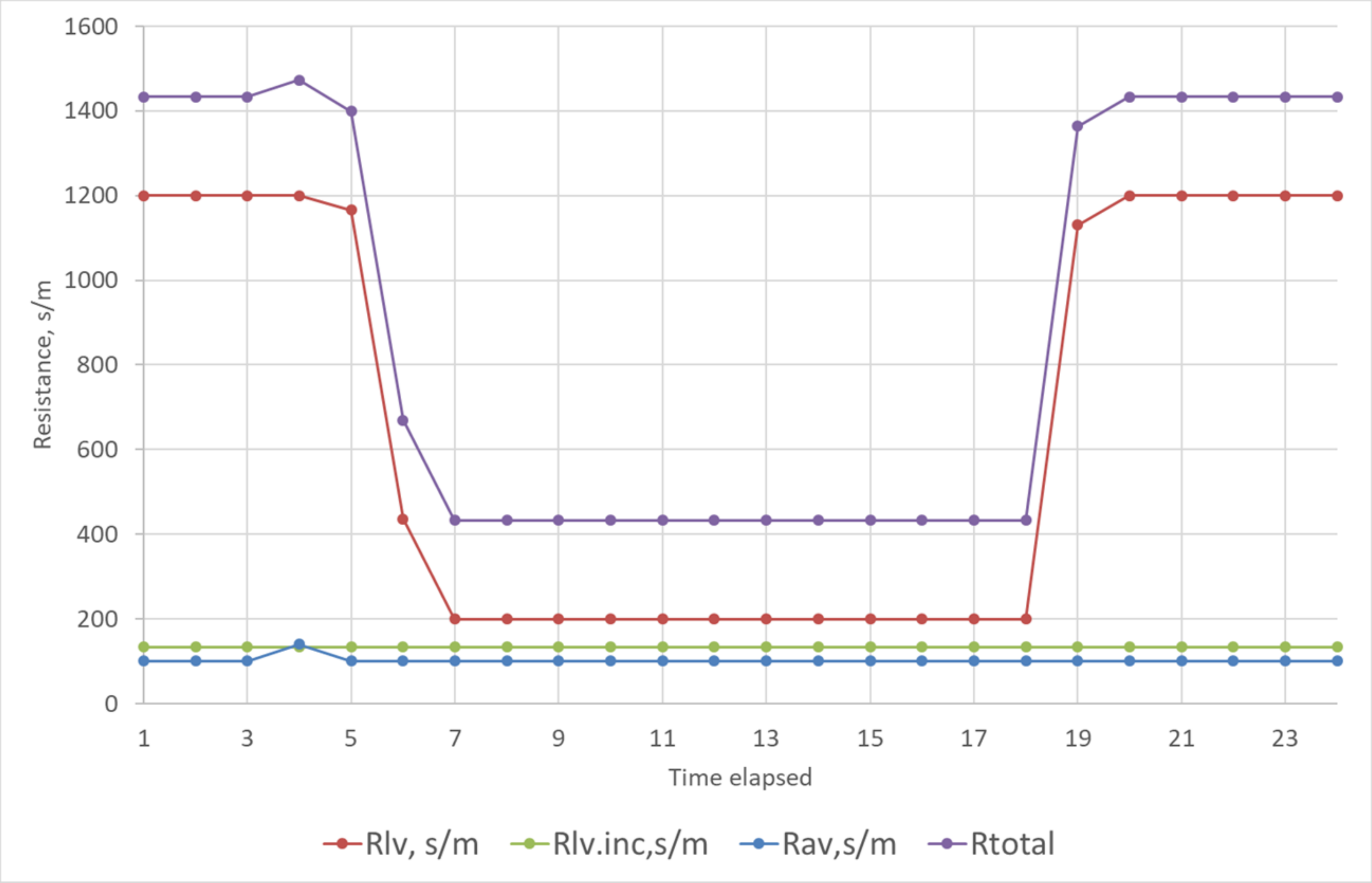
Tr=10364.63/424.5 = 24.42

Simulation Input temperature and humidity, then transpiration rate is calculated. The value of the following environmental factors can be changed: photosynthetically active irradiance, wind velocity, CO2 concentration, the reaction type to irradiance by plants, and the reaction type to CO2 concentration by plants.

Plant Type (Light)	Std.	Temp.	20 ℃	Ip	400 W/m²	Rav	100.0 s/m		
Plant Type (CO2)	Std.	W	1 m/s	CO2	400 ppm	Rlv	200.0 s/m		
		RH	40 %	CO2	732.1 mg/m³	Inc. of Rlv	124.5 s/m	Tr	24.42 mg/(m²s)

400 ppm * 44/(0.0821*(273.15+20)) = 400 * 1.83 = 732 mg/m³

溫室內針對水汽離開氣孔的逐時葉片邊界層阻力、氣孔阻力、氣孔阻力增量與總阻力



影響CO_2進出的氣孔阻力

- 作物型態、風速、光量、CO_2濃度

$R_{ac} = 1.65 * R_{av}$

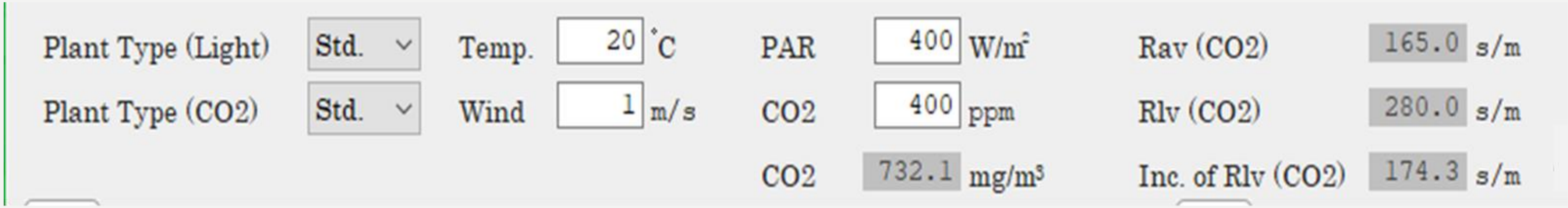
$R_{lc} = 1.4 * R_{lv}$

$R_{lc.inc} = 1.4 * R_{lv.inc}$

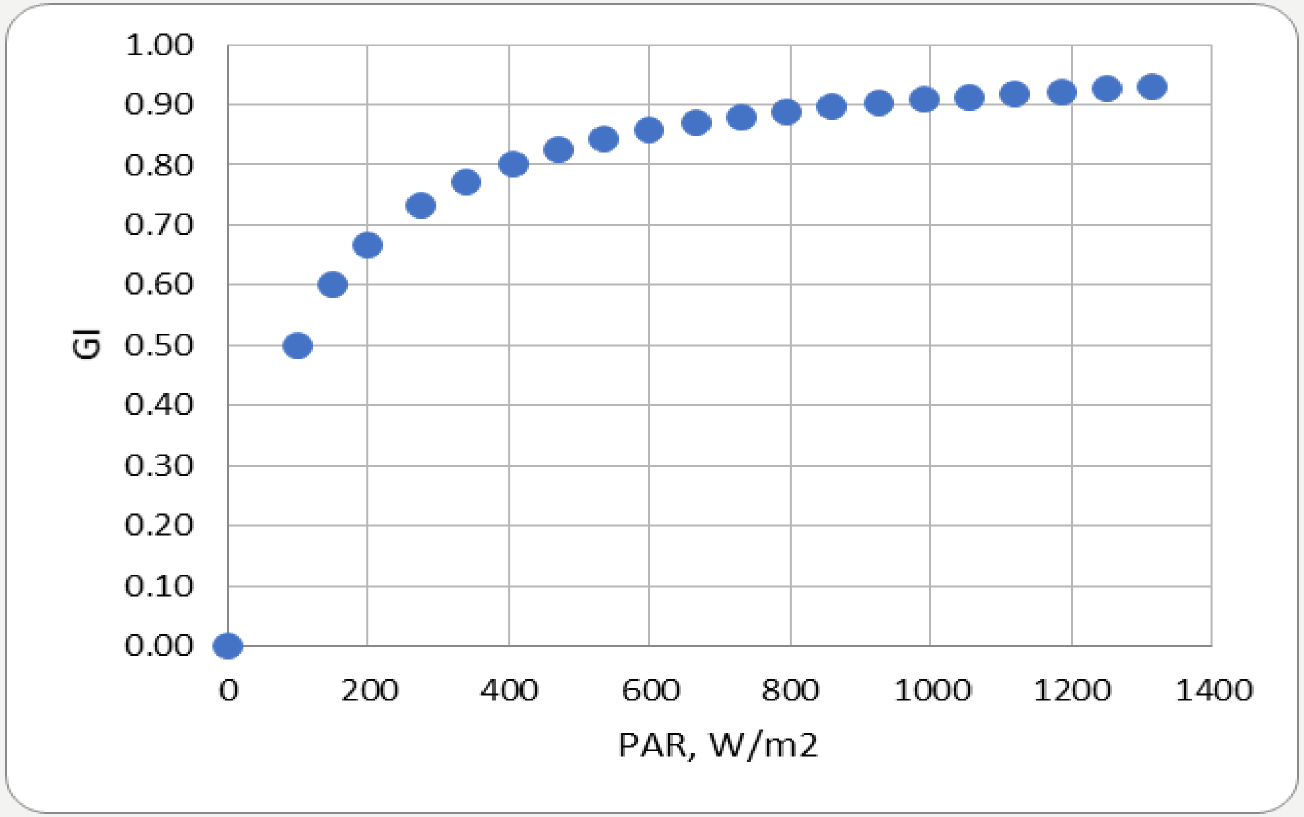
- $R_{c.total} = R_{ac} + R_{lc} + R_{lc.inc}$

Rlv.CO2	low	std	high due to light
Due to CO2: low	140	280	420
Due to CO2: std	140	280	420
Rav.CO2	165		
Rlv.inc.CO2	low	std	high due to light
Due to CO2: low	87.2	87.2	87.2
Due to CO2: std	174.3	174.3	174.3
R.total	low	std	high due to light
Due to CO2: low	392.2	532.2	672.2
Due to CO2: std	479.3	619.3	759.3

$R_{c.total}$ = 619.3 for std. light and std. CO_2 condition



影響光合作用速率的因子－光量（PAR）



$$G_I = \frac{1}{1+\frac{KI}{Ip}}$$

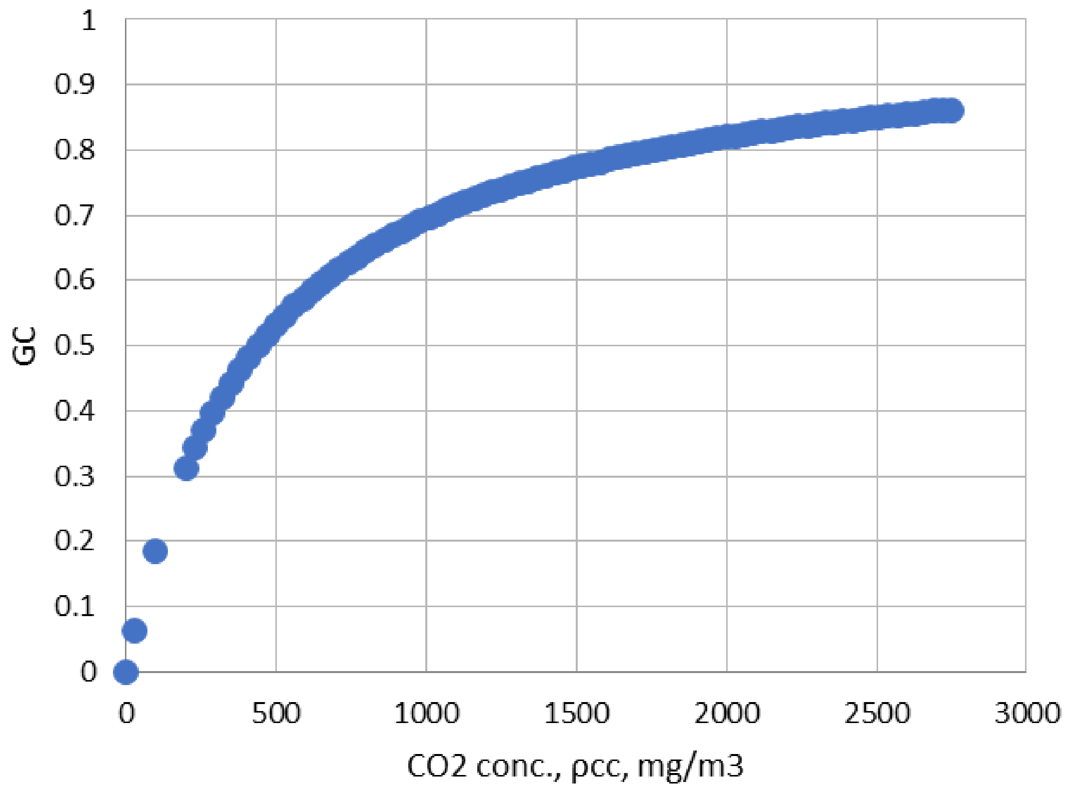
光量(輻射能)係數

GI : Light coefficient

KI : Rate constant of irradiance, W/m2

Ip : Photosynthetically active irradiance, W/m2
光合作用有效輻射能

影響光合作用速率的因子-CO_2濃度

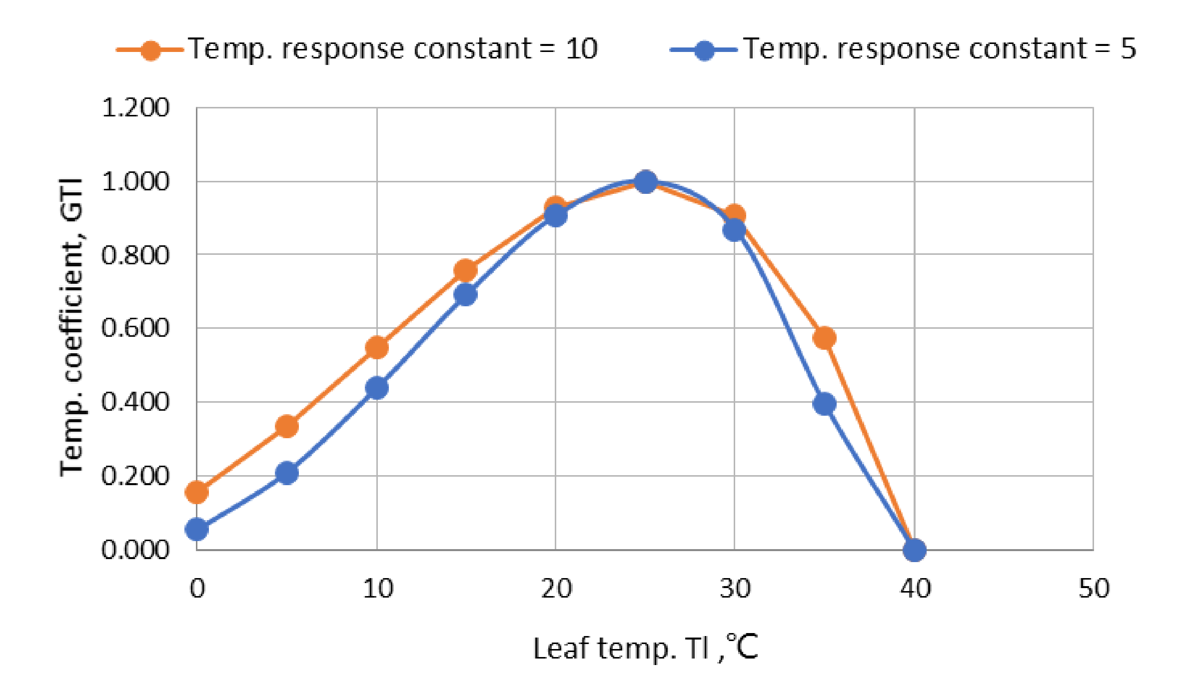


$$G_c = \frac{1}{1 + \frac{Kc}{\rho\, cc}}$$

二氧化碳係數

Gc	: CO2 coefficient
Kc	: Rate constant of CO2 concentration, mg/m3
ρ cc	: CO2 concentration in chloroplast, mg/m3

影響光合作用速率的因子－葉片溫度



Inputs			Outputs
Leaf temp. T_l , ℃	*Optimum leaf temp. for Pn.,* T_m , ℃	*Temp. response, a,* ℃	*Temp. coefficient,* G_{Tl}
20	25	5	**0.91**

溫度係數

$$G_{T_l} = \frac{2(T_l+a)^2(T_m+a)^2-(T_l+a)^4}{(T_m+a)^4}$$

G_{Tl} : Temperature coefficient

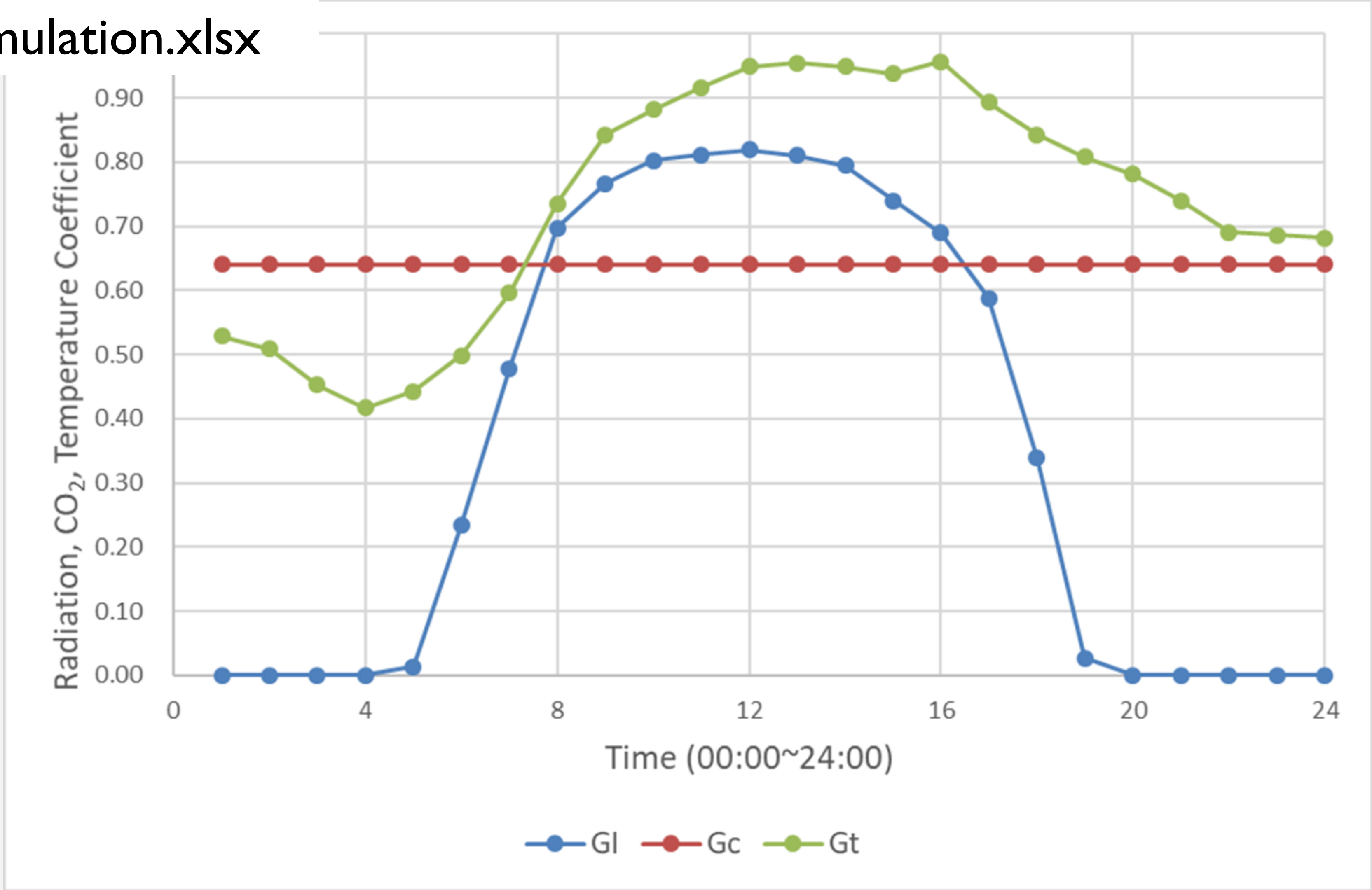
T_l : Leaf temperature, °C

T_m : Optimum leaf temperature for photosynthesis, °C

a : Temperature response constant, °C

溫室內24小時的逐時輻射能、二氧化碳與溫度係數

Pn simulation.xlsx



逐時輻射能 (G_I@K_I = 200 W/m^2)、二氧化碳 (G_c@ K_C = 440 mg/m^3) 與溫度係數 (G_t@T_m = 25 ^{o}C, a = 5 ^{o}C)

Pn simulation.xlsx

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Assump	PhotoResp/Ph	Dark Respiration	氣孔阻力 (CO_2)								P=(B-sqrt(B^2-4AC))/2/A		
2	hr:mn	Kpr	Rd,mg/(m3.	Rac	Rlc	Rlc.inc	Rc	Pm	-B=Rho.c	4*Rc*Rho.ca	B^2-4AC	Photosynthesi	PhotoResp	Net PhotoS.
3	1	0.3333	0.0397	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0397
4	2	0.3333	0.0386	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0386
5	3	0.3333	0.0357	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0357
6	4	0.3333	0.0340	231										-0.0340
7	5	0.3333	0.0352	165										-0.0301
8	6	0.3333	0.0380	165										0.0547
9	7	0.3333	0.0434	165										0.1725
10	8	0.3333	0.0527	165										0.2948
11	9	0.3333	0.0522	165	280	186.67	631.67	1.292753	2040.589	2560823	1603180	0.6129985	0.204333	0.3464
12	10	0.3333	0.0567	165	280	186.67	631.67	1.415915	2118.387	2804796	1682765	0.6500043	0.216668	0.3667
13	11	0.3333	0.0715	165	280	186.67	631.67	1.487097	2163.35	2945801	1734281	0.6699963	0.223332	0.3752
14	[illegible]	0.3333	0.0771	165	280	186.67	631.67	1.556018	2206.885	3082326	1788013	0.6884314	0.229477	0.3818
15										3065015	1780990	0.6861426	0.228714	0.3792
16										2987311	1750217	0.6756955	0.225232	0.3733
17										2751007	1664179	0.6421138	0.214038	0.3531
18	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	631.67	1.319984	2057.79	2614765	1619734	0.6214528	0.207151	0.3355
19	17	0.3333	0.0681	165	280	186.67	631.67	1.051041	1887.908	2082014	1482181	0.5307064	0.176902	0.2857
20	18	0.3333	0.0622	165	280	186.67	631.67	0.572138	1585.401	1133352	1380143	0.3250178	0.108339	0.1545
21	19	0.3333	0.0589	165	1582.78	186.67	1934.44	0.043717	1308.569	265208	1447145	0.0272935	0.009098	-0.0407
22	20	0.3333	0.0565	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0565
23	21	0.3333	0.0531	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0531
24	22	0.3333	0.0495	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0495
25	23	0.3333	0.0492	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0492
26	24	0.3333	0.0488	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0488
27														

$$RESP_{dark} = Rd_{20} * Q10^{((T_l-20)/10)}$$

$$= 0.07 * 2^{((T_l-20)/10)}$$

暗呼吸速率 $RESP_{dark}$

Pn simulation.xlsx

光合速率 P

$$y = a \cdot x^2 + b \, . \, x + c$$

$$x = \frac{-b - \sqrt{b^2 - 4\,a\,c}}{2\,a}$$

$$R \cdot P^2 - (C_a + K_c + R\,P_{sc})\,P + P_{sc} C_a = 0$$

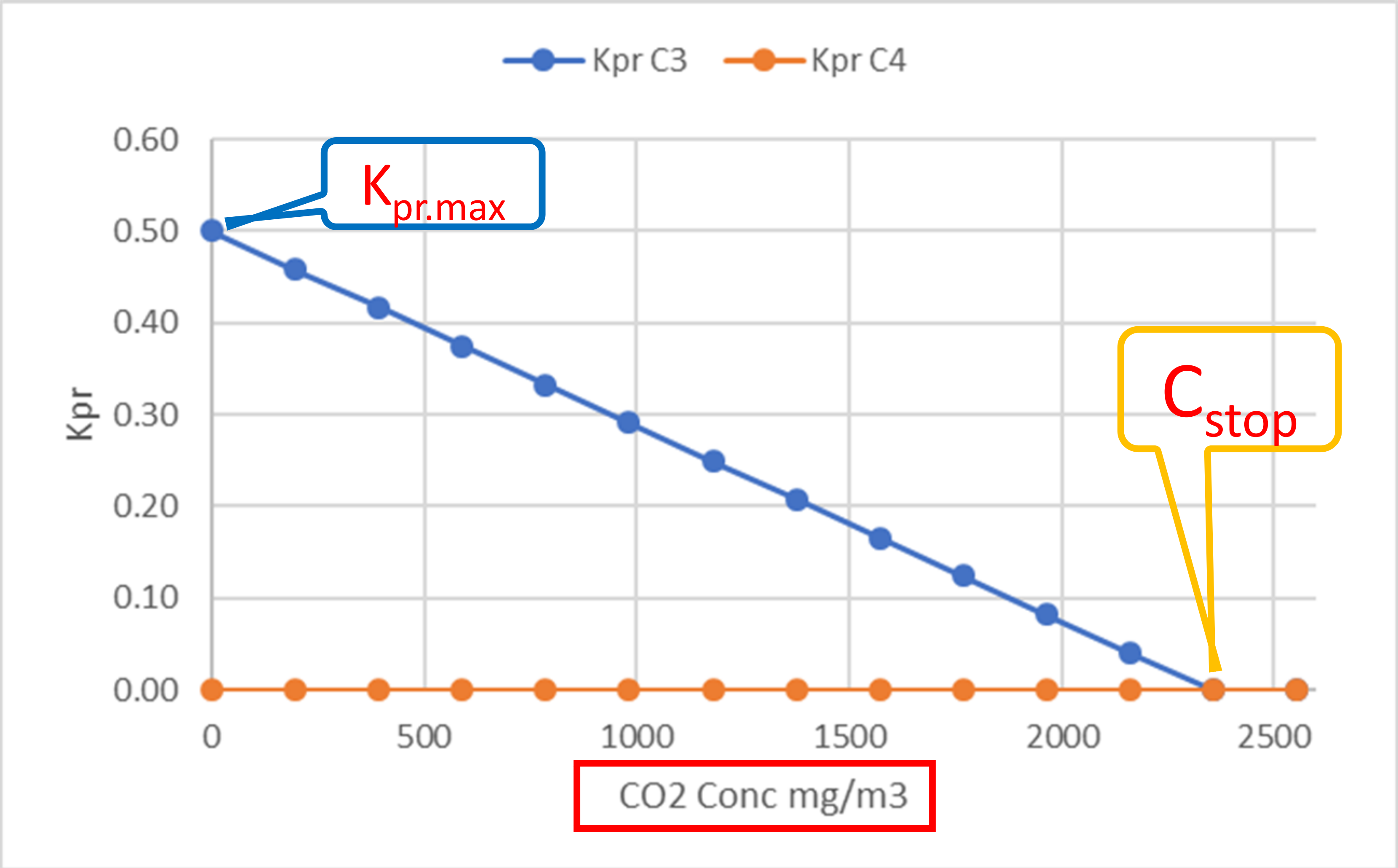
$$P = \frac{(C_a + K_c + R\,P_{sc}) - \sqrt{(C_a + K_c + R\,P_{sc})^2 - 4\,R\,P_{sc} C_a}}{2\,R}$$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Assump	hotoResp/Ph	Dark Respiration									P=(B-sqrt(B^2-4AC))/2/A		
2	hr:mn	Kpr	Rd,mg/(m3.s	Rac	Rlc	Rlc.inc	Rc	Pm	-B=Rho.c	4*Rc*Rho.ca	B^2-4AC	Photosynthesis	PhotoResp	Net PhotoS.
3	1	0.3333	0.0397	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0397
4	2	0.3333	0.0386	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0386
5						6.67	2031.67	0	1224	0	1498176	0	0	-0.0357
6						6.67	2097.67	0	1224	0	1498176	0	0	-0.0340
7						6.67	1983.06	0.012126	1248.047	75411	1482210	0.0077119	0.002571	-0.0301
8											1394138	0.1390997	0.046367	0.0547
9	7	0.3333	0.0434								1380093	0.3238413	0.107947	0.1725
10	8	0.3333	0.0527								1472196	0.5212878	0.173763	0.2948
11	9	0.3333	0.0622								1603180	0.6129985	0.204333	0.3464
12	10	0.3333	0.0667								1682765	0.6500043	0.216668	0.3667
13	11	0.3333	0.0715								1734281	0.6699963	0.223332	0.3752
14	12	0.3333	0.0771								1788013	0.6884314	0.229477	0.3818
15	13	0.3333	0.0782								1780990	0.6861426	0.228714	0.3792
16	14	0.3333	0.0771	165	280	186.67	631.67	1.508052	2176.586	2987311	1750217	0.6756955	0.225232	0.3733
17	15	0.3333	0.0750	165	280	186.67	631.67	1.388761	2101.234	2751007	1664179	0.6421138	0.214038	0.3531
18	16	0.3333											0.207151	0.3355
19	17	0.3333											0.176902	0.2857
20	18	0.3333	0.0622	165	280	186.67	631.67	0.572138	1585.401	1133352	1380143	0.3250178	0.108339	0.1545
21	19												009098	-0.0407
22	20												0	-0.0565
23	21												0	-0.0531
24	22												0	-0.0495
25	23	0.3333	0.0492	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0492
26	24	0.3333	0.0488	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0488
27														

光呼吸速率 $RESP_{photo}$

$$RESP_{photo} = K_{pr} * P$$

$$K_{pr} = -K_{pr.max} / C_{stop} * (C_a - C_{stop})$$



K_{pr}計算與單位換算 ppm → mg/m^3

$K_{pr} = -K_{pr.max} / C_{stop} * (C_a - C_{stop}) = -0.5/2352.7 * (Ca – 2352.7)$

$mg/m^3 = ppm * 44.01 / 22.4 * 273/(273+T_a)$

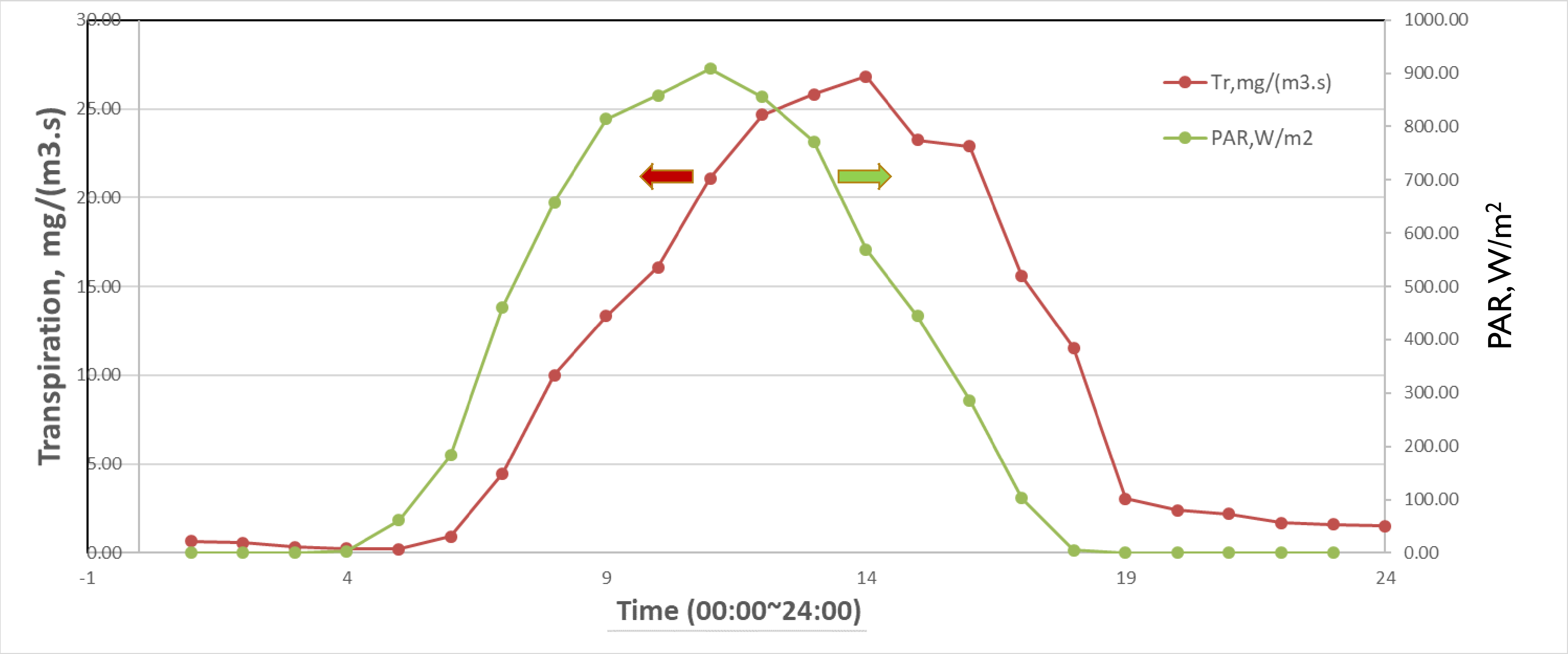
Inputs				Outputs	
Plant Type	Temp. (℃)		CO_2 conc. (ppm)	CO_2 conc. (mg/m^3)	Kpr
C3	0	1.96	1000	1964.7	0.08
C3	0		1200	2352.7	0
C3	20	1.828	1000	1830.6	0.11
C3	20		500	915.3	0.31
C3	10	1.8927	500	947.7	0.30
C3	0		500	982.4	0.29
C4	0		500	982.4	0

Density = M/(RT) = 44/(0.0821 * (273.15+Ta)

24小時的模擬

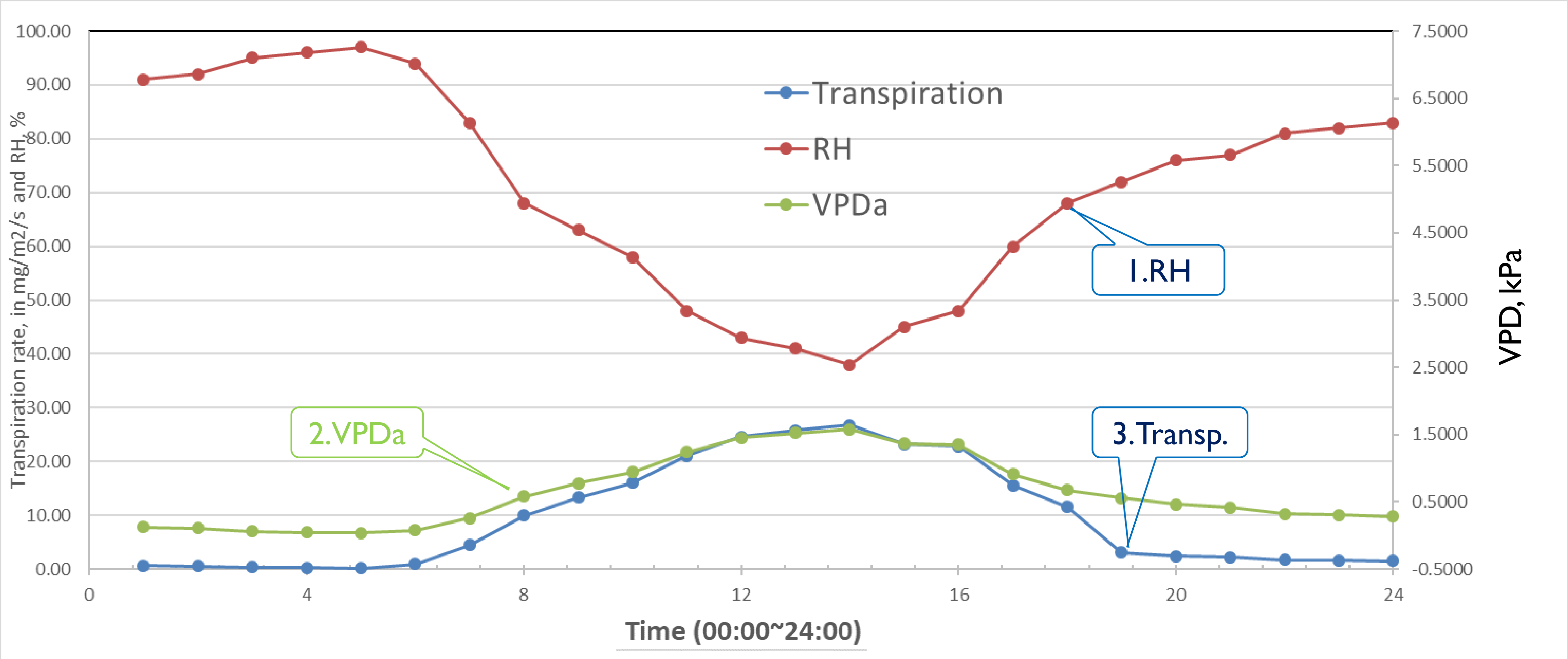
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Assumption		Pmax=	3.123136		Q10=	2	Rd(20C)=	0.07		Kc=	440			
2	hr:mn	T,°C	RH,%	Wind,m/s	PAR,MJ/m	CO2,ppm	PAR,W/m2	CO2,mg/m	Vps,g/m3	Vds, g/m3	Vd,g/m3	Rlv, s/m	Rav,s/m	Rlv.inc,	Tr,mg/(m3.s
3	1	11.8	91	2.3	0	400	0.00	784	1.38	10.52	9.57	1200	100	133	0.66
4	2	11.4	92	2.1	0	400	0.00	784	1.35	10.26	9.44	1200	100	133	0.57
5	3	10.3	95	1.9	0	400	0.00	784	1.25	9.57	9.09	1200	100	133	0.33
6	4	9.6	96	0.6	0	400	0.00	784	1.20	9.16	8.79	1200	140	133	0.25
7	5	10.1	97	2.6	0.01	400	2.78	784	1.24	9.45	9.17	1165	100	133	0.20
8	6	11.2	94	1.2	0.22	400	61.11	784	1.33	10.13	9.52	436	100	133	0.91
9	7	13.1	83	2.1	0.66	400	183.33	784	1.51	11.41	9.47	200	100	133	4.47
10	8	15.9	68	2.2	1.66	400	461.11	784	1.81	13.54	9.21	200	100	133	10.00
11	9	18.3	63	1.4	2.37	400	658.33	784	2.10	15.63	9.85	200	100	133	13.34
12	10	19.3	58	1.2	2.93	400	813.89	784	2.24	16.58	9.62	200	100	133	16.07
13	11	20.3	48	2.3	3.09	400	858.33	784	2.38	17.58	8.44	200	100	133	21.10
14	12	21.4	43	2.7	3.27	400	908.33	784	2.55	18.74	8.06	200	100	133	24.65
15	13	21.6	41	3.3	3.08	400	855.56	784	2.58	18.96	7.77	200	100	133	25.81
16	14	21.4	38	4	2.78	400	772.22	784	2.55	18.74	7.12	200	100	133	26.81
17	15	21	45	4.4	2.05	400	569.44	784	2.49	18.31	8.24	200	100	133	23.24
18	16	21.7	48	3.7	1.6	400	444.44	784	2.60	19.07	9.15	200	100	133	22.88
19	17	19.6	60	4	1.03	400	286.11	784	2.28	16.87	10.12	200	100	133	15.58
20	18	18.3	68	4.1	0.37	400	102.78	784	2.10	15.63	10.63	200	100	133	11.54
21	19	17.5	72	3.1	0.02	400	5.56	784	2.00	14.90	10.73	1131	100	133	3.06
22	20	16.9	76	2.7	0	400	0.00	784	1.93	14.38	10.93	1200	100	133	2.41
23	21	16	77	2.1	0	400	0.00	784	1.82	13.62	10.49	1200	100	133	2.19
24	22	15	81	2.6	0	400	0.00	784	1.71	12.82	10.38	1200	100	133	1.70
25	23	14.9	82	2.2	0	400	0.00	784	1.69	12.74	10.45	1200	100	133	1.60
26	24	14.8	83	2.5	0	400	0.00	784	1.68	12.66	10.51	1200	100	133	1.50
27															

蒸散與太陽能的波鋒有個時間差

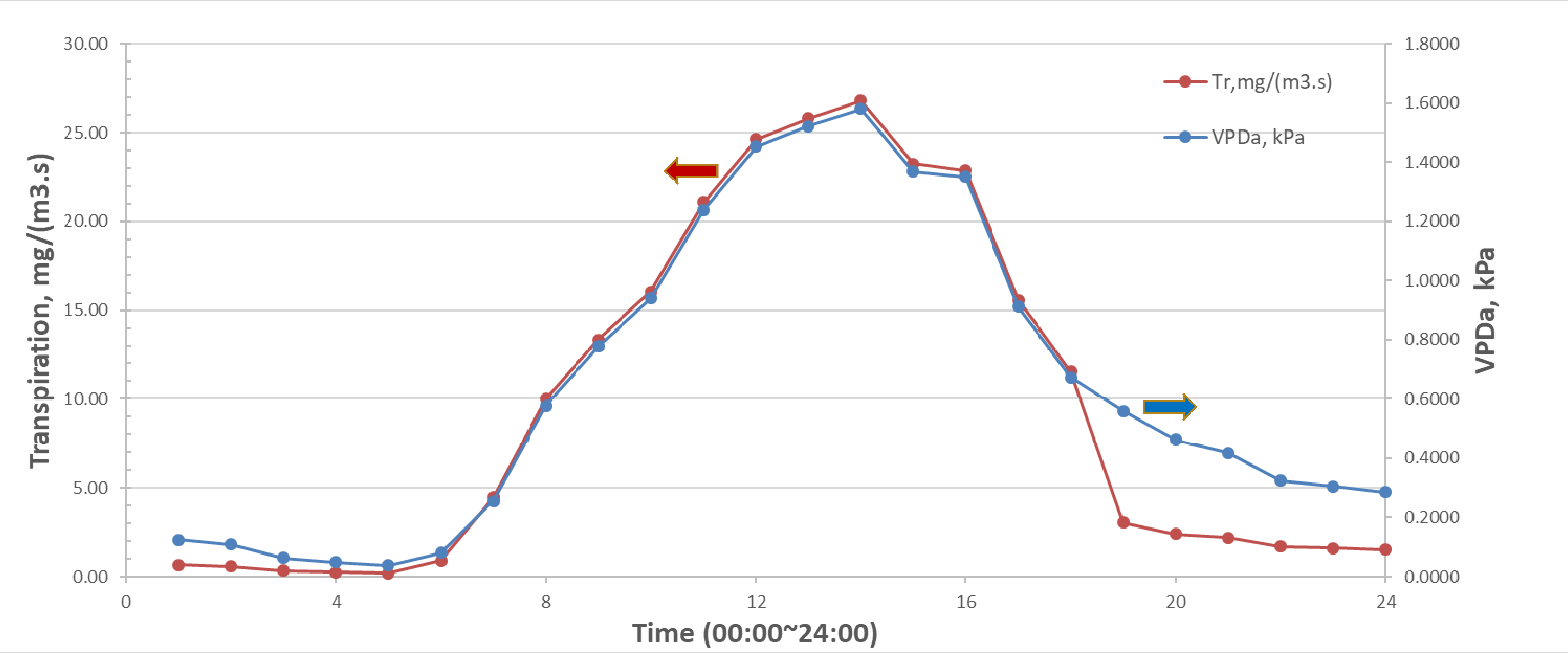


1 ↓ 2 ↓ 3 ↓

1	Assumption		Pmax=	3.123136			Q10=	2	Rd(20C)=	0.07		Kc=	440			
2	hr:mn	T,°C	RH,%	Wind,m/s	VPDa	PAR,MJ/m	CO2,ppm	PAR,W/m2	CO2,mg/m	Vps,g/m3	Vds, g/m3	Vd,g/m3	Rlv, s/m	Rav,s/m	Rlv.inc,s/m	Tr,mg/(m3.s
3	1	11.8	91	2.3	0.1246	0	400	0.00	784	1.38	10.52	9.57	1200	100	133	0.66
4	2	11.4	92	2.1	0.1078	0	400	0.00	784	1.35	10.26	9.44	1200	100	133	0.57
25	23	14.9	82	2.2	0.3050	0	400	0.00	784	1.69	12.74	10.45	1200	100	133	1.60
26	24	14.8	83	2.5	0.2862	0	400	0.00	784	1.68	12.66	10.51	1200	100	133	1.50



蒸散與VPD的波鋒大致吻合



Pn simulation.xlsx

1 2 3 4

淨光合速率 Pn

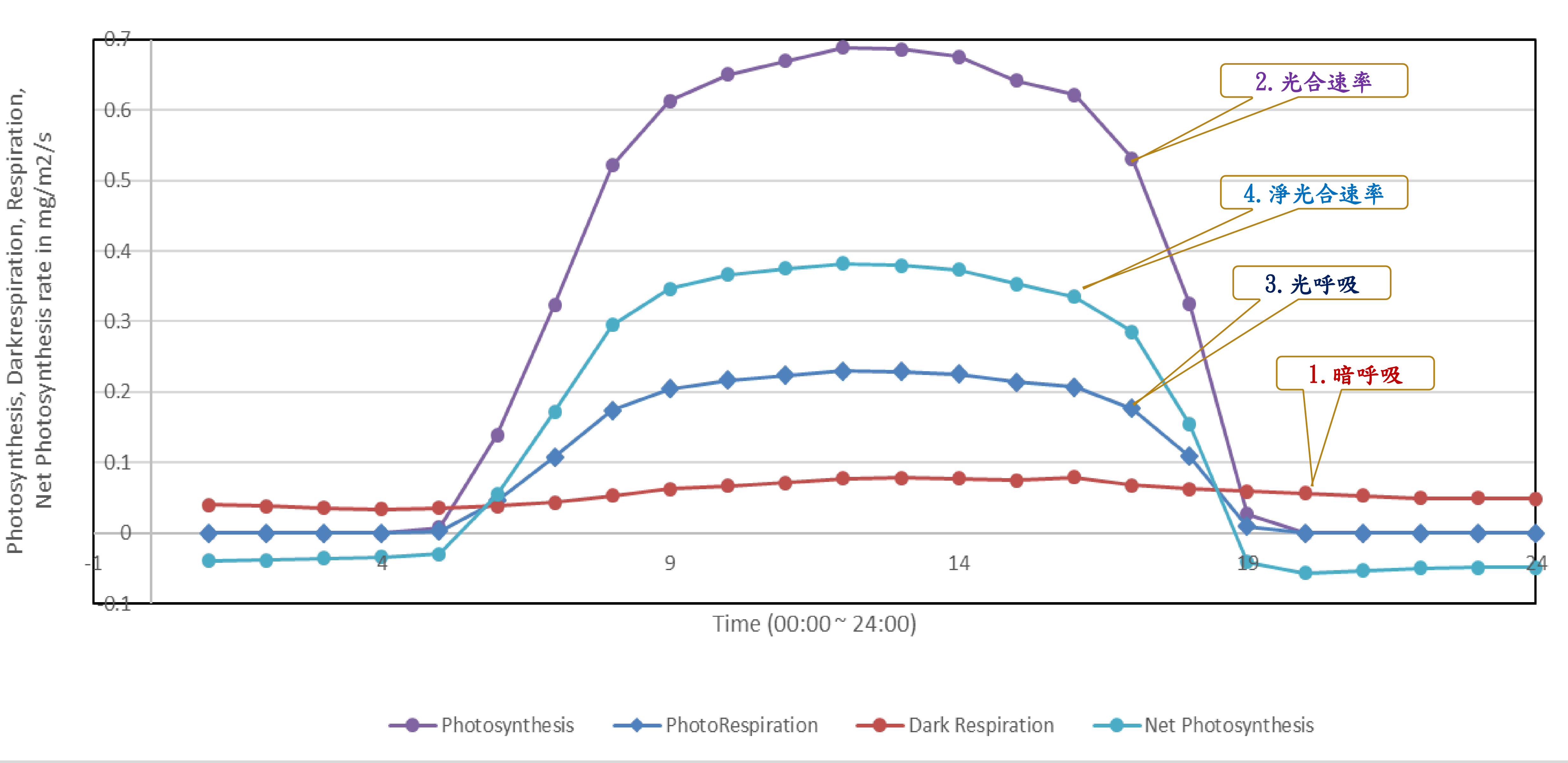
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Assump	hotoResp/Ph	Dark Respiration							A*C		P=(B-sqrt(B^2-4AC))/2/A		
2	hr:mn	Kpr	Rd,m3/m3	Rac	Rlc	Rlc.inc	Rc	Pm	-B=Rho.c	4*Rc*Rho.ca	B^2-4AC	Photosynthesis	PhotoResp	Net PhotoS.
3	1	0.3333	0.0397	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0397
4								0	1224	0	1498176	0	0	-0.0386
5								0	1224	0	1498176	0	0	-0.0357
6								0	1224	0	1498176	0	0	-0.0340
7								126	1248.047	75411	1482210	0.0077119	0.002571	-0.0301
8	6	0.3333	0.0380	165	611	186.67	962.22	0.233237		703799	1394138	0.1390997	0.046367	0.0547
9	7	0.3333	0.0434	165	280	186.67	631.67	0.569751	1583.893	1128624	1380093	0.3238413	0.107947	0.1725
10	8	0.3333	0.0527	165	280	186.67	631.67	1.025701	1871.901	2031817	1472196	0.5212878	0.173763	0.2948
11	9	0.3333	0.0622	165	280	186.67	631.67	1.292753	2040.589	2560823	1603180	0.6129985	0.204333	0.3464
12	10													0.3667
13	11													0.3752
14	12													0.3818
15	13	0.3333	0.0782										0.228714	0.3792
16	14	0.3333	0.0771										0.225232	0.3733
17	15	0.3333	0.0750										0.214038	0.3531
18	16	0.3333	0.0788	165	280	186.67	631.67	1.319984	2057.79	2614765	1619734	0.6214528	0.207151	0.3355
19	17	0.3333	0.0681	165	280	186.67	631.67	1.051041	1887.908	2082014	1482181	0.5307064	0.176902	0.2857
20	18	0.3333	0.0622	165	280	186.67	631.67	0.572138	1585.401	1133352	1380143	0.3250178	0.108339	0.1545
21	19	0.3333	0.0589	165	1582.78	186.67	1934.44	0.043717	1308.569	265208	1447145	0.0272935	0.009098	-0.0407
22	20	0.3333	0.0565	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0565
23	21	0.3333	0.0531	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0531
24	22	0.3333	0.0495	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0495
25	23	0.3333	0.0492	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0492
26	24	0.3333	0.0488	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0488
27														

淨光合速率 = 光合速率 − 暗呼吸 − 光呼吸

$$Pn = P - RESP_{dark} - RESP_{photo}$$

Pn simulation.xlsx

1	Assump		PhotoResp/Ph	Dark Respiration						'A*C			P=(B-sqrt(B^2-4AC))/2/A		
2	hr:mn		Kpr	Rd,mg/(m3.s	Rac	Rlc	Rlc.inc	Rc	Pm	-B=Rho.c	4*Rc*Rho.ca	B^2-4AC	Photosynthesis	PhotoResp	Net PhotoS.
3	1		0.3333	0.0397	165	1680	186.67	2031.67	0	1224	0	1498176	0	0	-0.0397



光合速率vs. PAR 輻射能

Pn simulation.xlsx