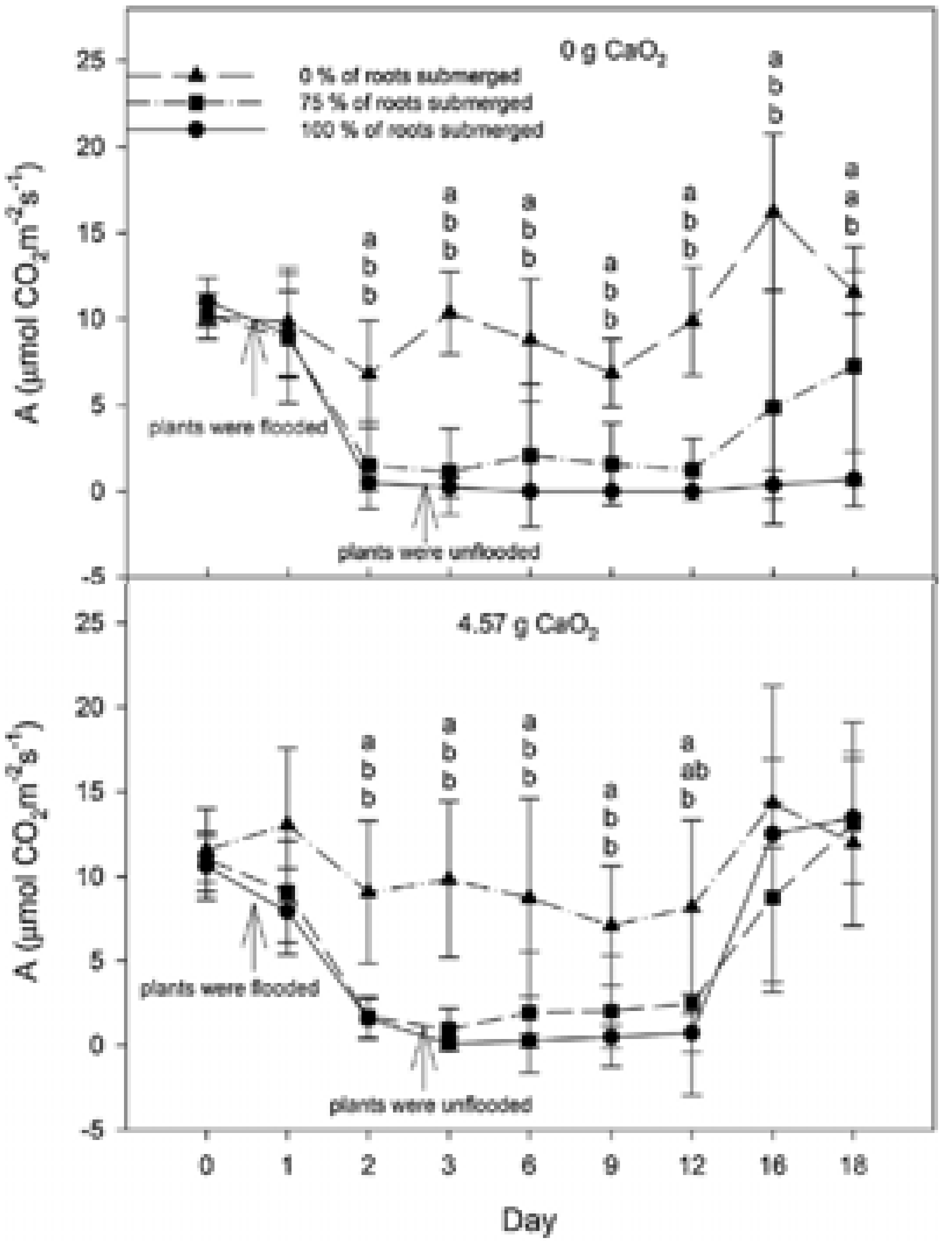
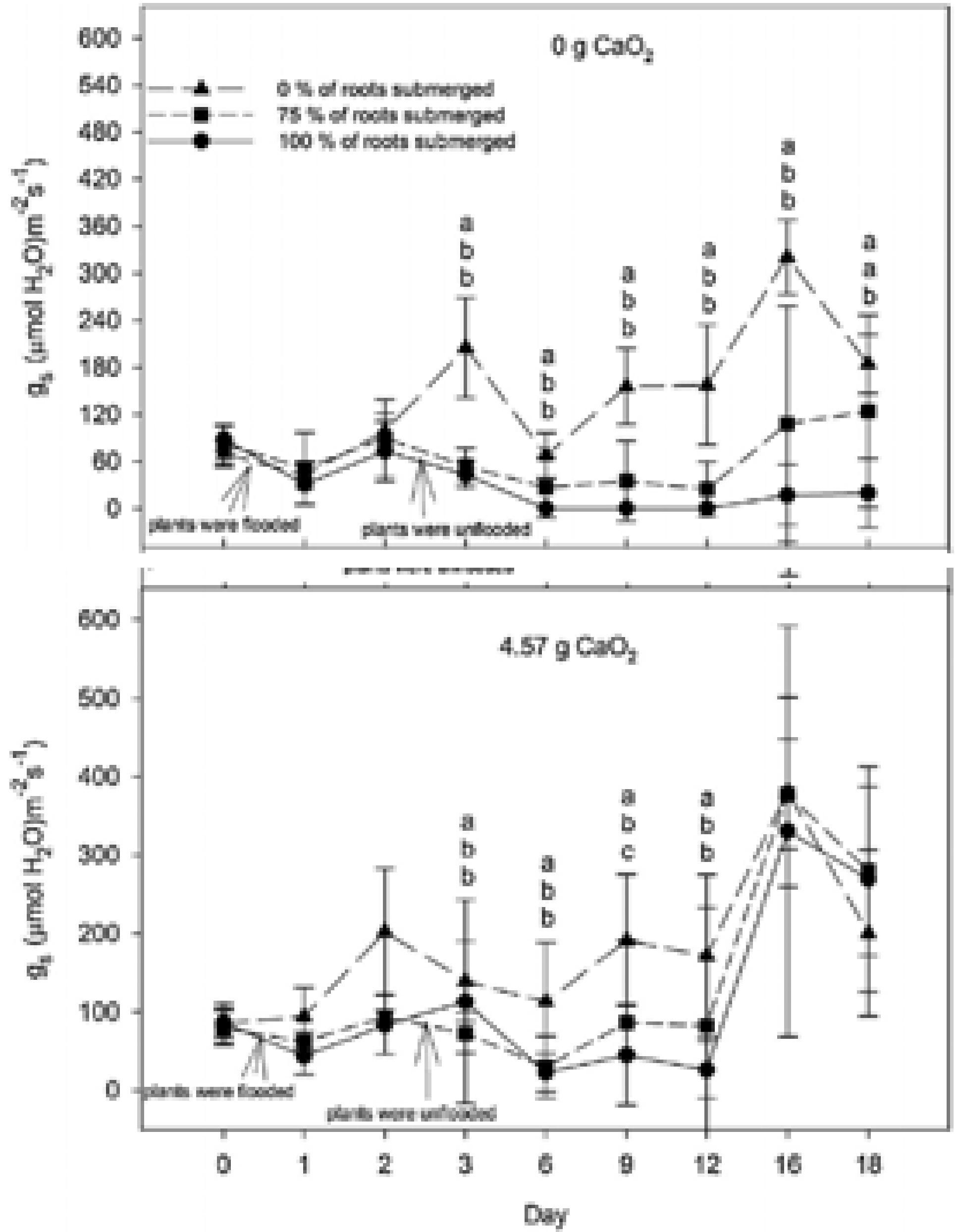
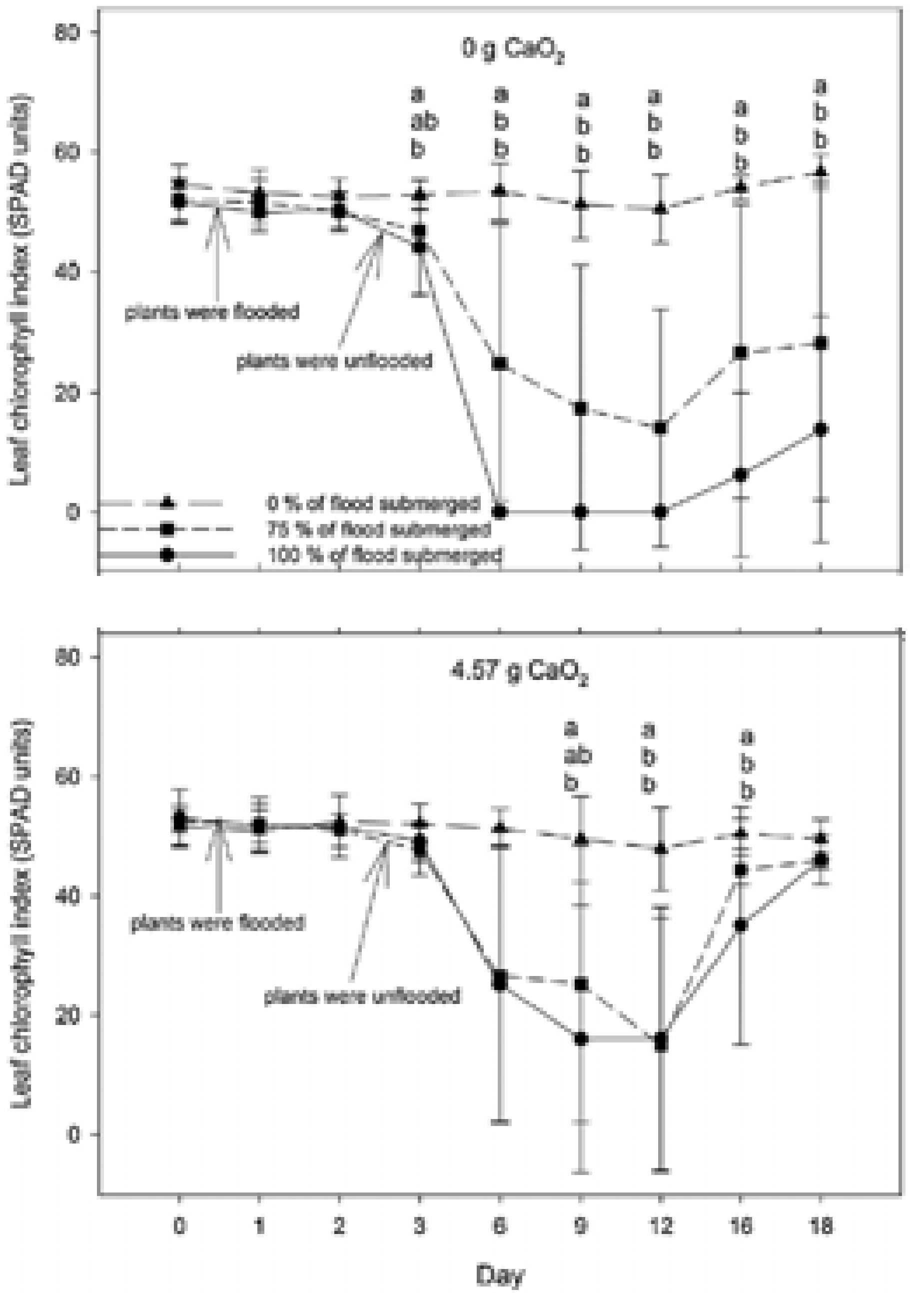
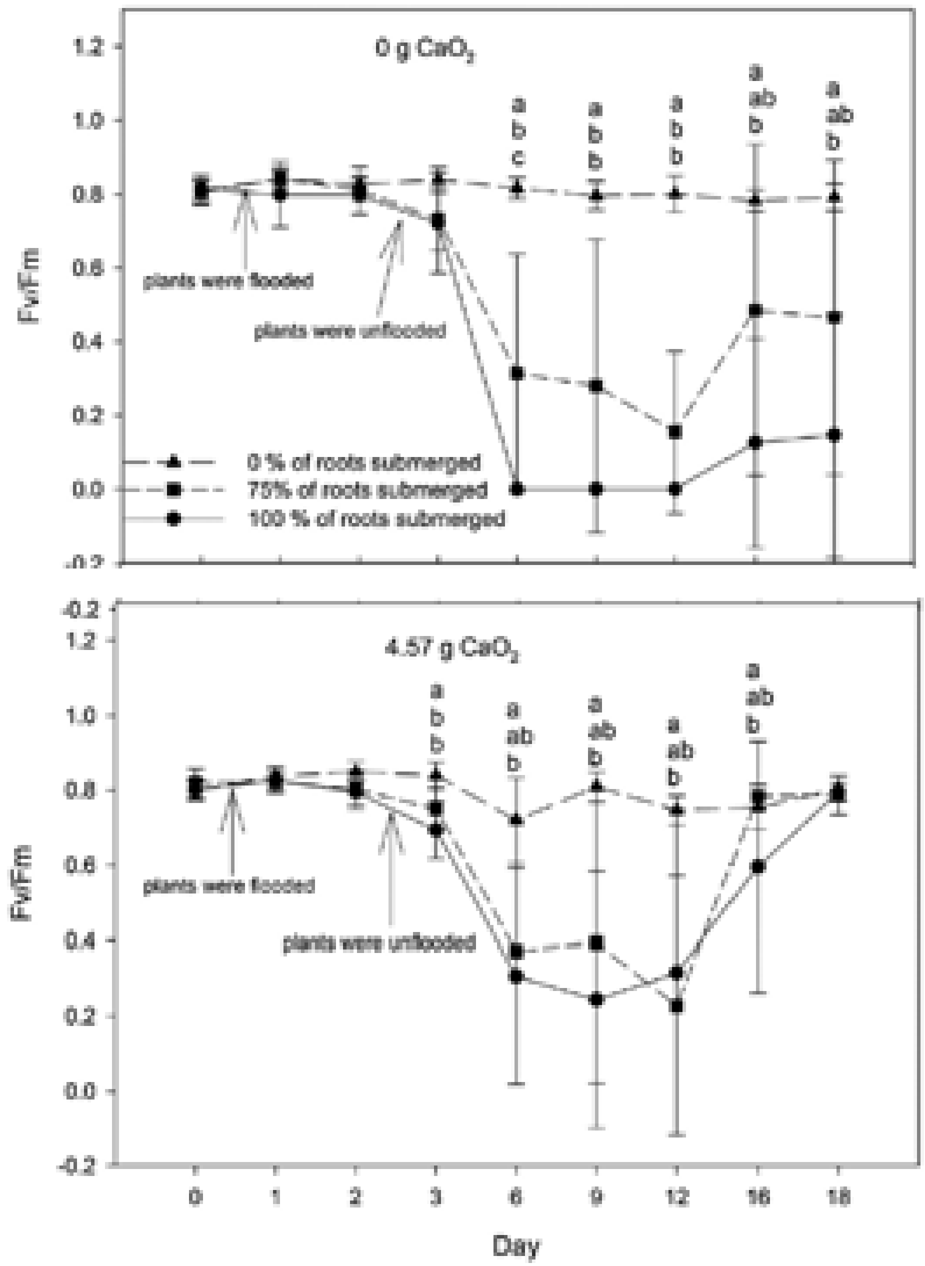


2.5-l plastic bucket

pots (Thani, 2016). Calculations were then made to account for the smaller pot size in the present experiment. CaO_2 was applied evenly to the soil surface a few minutes prior to beginning the flooding treatments. Treatments were arranged in a randomized complete


0 g CaO_2
0 % of roots submerged
75 % of roots submerged
100 % of roots submerged
plants were flooded
plants were unflooded
g_s (μmol H_2O)$m^{-2}s^{-1}$)
4.57 g CaO_2
plants were flooded
plants were unflooded
g_s (μmol H_2O)$m^{-2}s^{-1}$)
Day

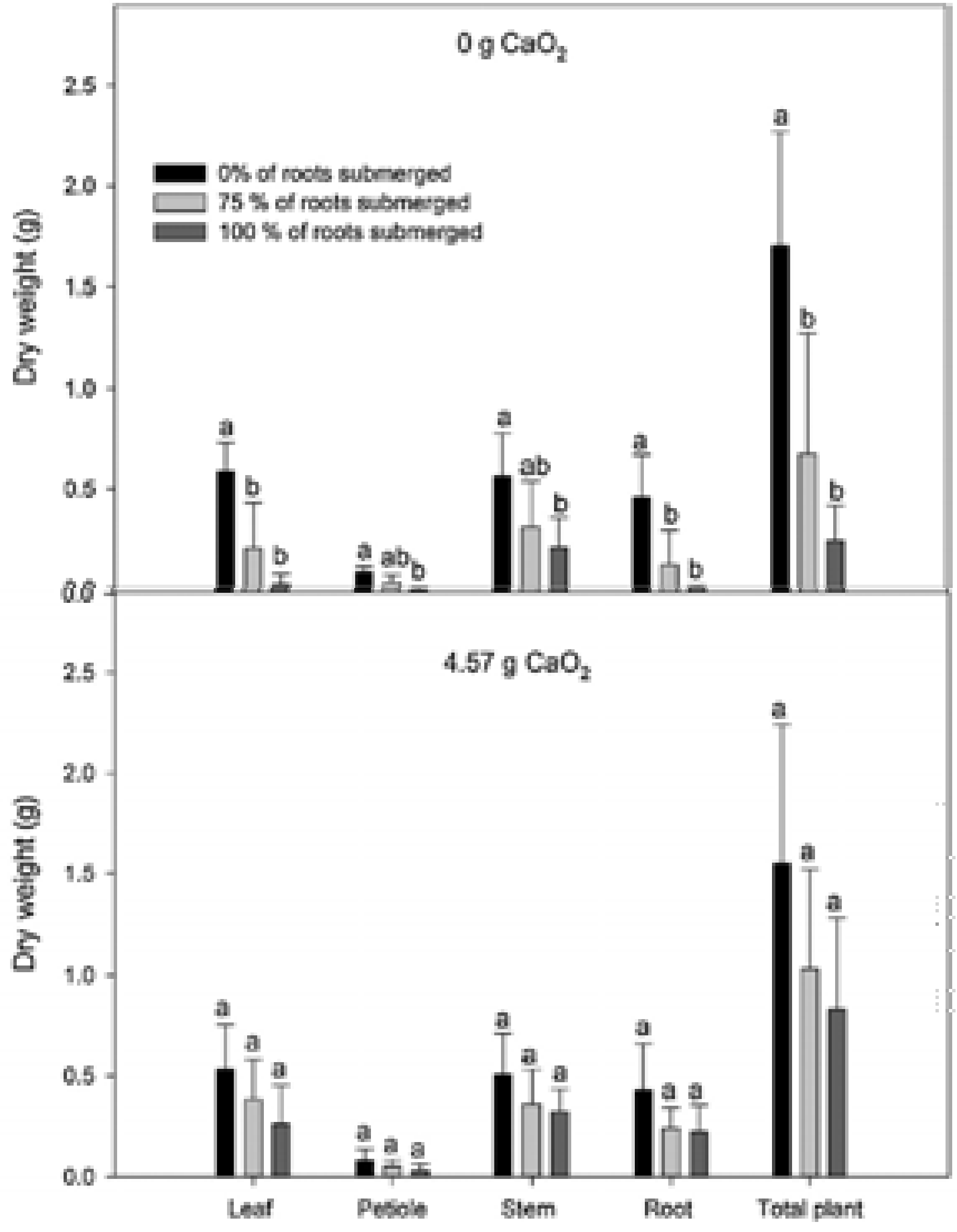

0 g CaO_2
4.57 g CaO_2
Leaf chlorophyll index (SPAD units)
plants were flooded
plants were unflooded
0 % of flood submerged
75 % of flood submerged
100 % of flood submerged
Day
0
1
2
3
6
9
12
16
18



0 g CaO_2
plants were flooded
plants were unflooded
0 % of roots submerged
75% of roots submerged
100 % of roots submerged
Fv/Fm
4.57 g CaO_2
Day

Table 2
Survival of papaya (*Carica papaya* L.) seedlings in Krome very gravelly loam soil with 0%, ~75%, or 100% of roots submerged in H_2O with different concentrations of CaO_2 added to the soil (Experiment 1).

CaO_2 application rate (g)	Amount of roots submerged (%)		
	0	~75	100
	Plant survival (%)		
0	100	60	40
2.28	100	80	80
4.57	100	100	100



0 g CaO_2
0% of roots submerged
75 % of roots submerged
100 % of roots submerged
Dry weight (g)
4.57 g CaO_2
Dry weight (g)
Leaf
Petiole
Stem
Root
Total plant

Salinity

Papaya seed germination is inhibited by very low levels of salinity (Kottenmeier et al., 1983), yet seedling growth can be stimulated by 1/10 seawater salinity levels (8 mS cm^{-1}) when compared to a Hoagland's nutrient solution control (Kottenmeier et al., 1983)

Maas (1993), however, classified papaya production as moderately sensitive with salinity effects at 3 mS cm^{-1}

Similarly Elder et al. (2000) found that moderately saline water (1.4 to 4 mS cm^{-1}) applied in trickle or under-tree mini-sprinkler irrigation had no adverse affect on productivity but when overhead applied, there was leaf damage and reduced growth.

seawater:
3.5% (35 g/L, or 599 mM)
50-80 mS cm^{-1}
Hoagland solution:
2.7 mS cm^{-1}

1 mS cm^{-1} = 1 dS m^{-1}

3200 ppm (mg L^{-1}) de NaCl equivale a 5 dS m^{-1}

3.2 g NaCl 1Litro de água = 5 dS m^{-1}

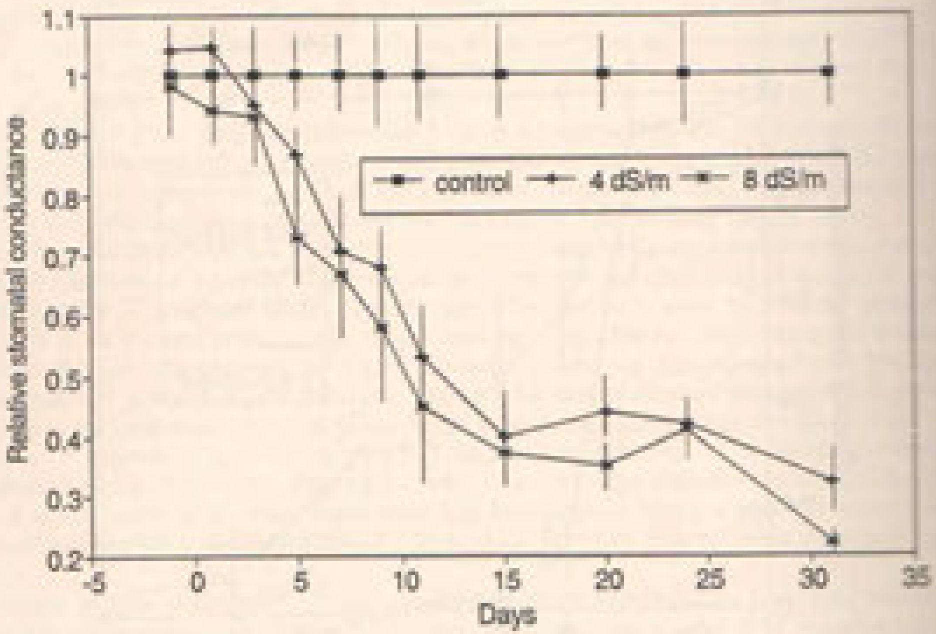


Figure 12 The time course of stomatal conductance of papaya leaves relative to that of control plants as influenced by salinity of irrigation water. Data were standardized as a fraction of control (Marler, T. E. unpublished data, 1990.)

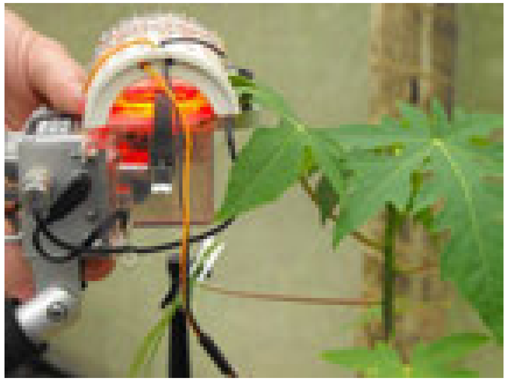
The experiment was conducted in a greenhouse between March and October 2010, at UENF, in Campos dos Goytacazes, RJ

2 genotypes: Golden and UENF/Caliman

100L pots

EC 1; 1.6; 2.2; 2.8; and 3.4 dS m^{-1}

96 to 126 Days after transplanting



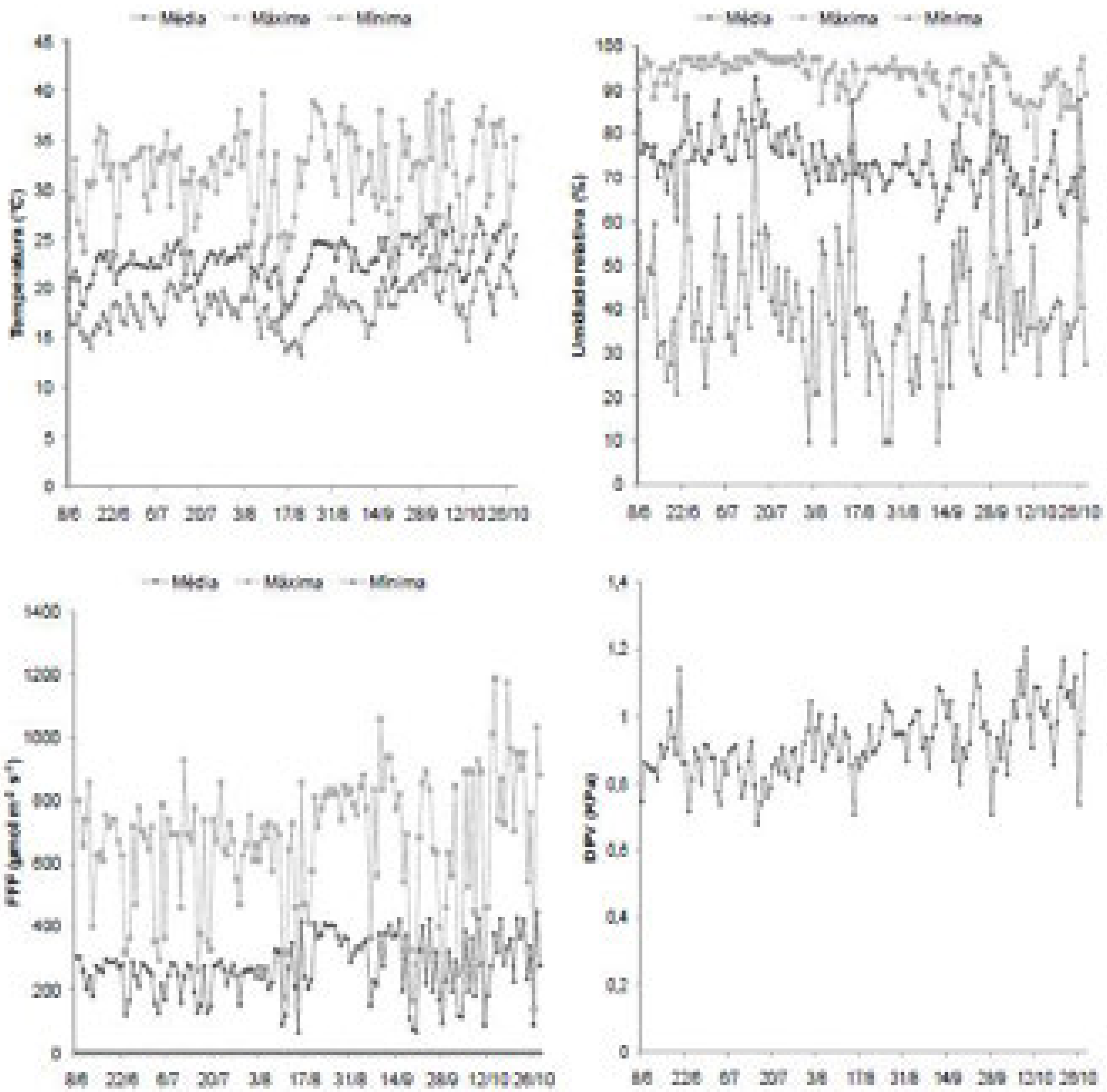
* Control.

The experiment was conducted in a greenhouse between March and October 2010, at UENF, in Campos dos Goytacazes, RJ

2 genotypes: Golden and UENF/Caliman

100L pots

EC 1; 1.6; 2.2; 2.8; and 3.4 dS m^{-1}



* Control.

The experiment was conducted in a greenhouse between March and October 2010, at UENF, in Campos dos Goytacazes, RJ

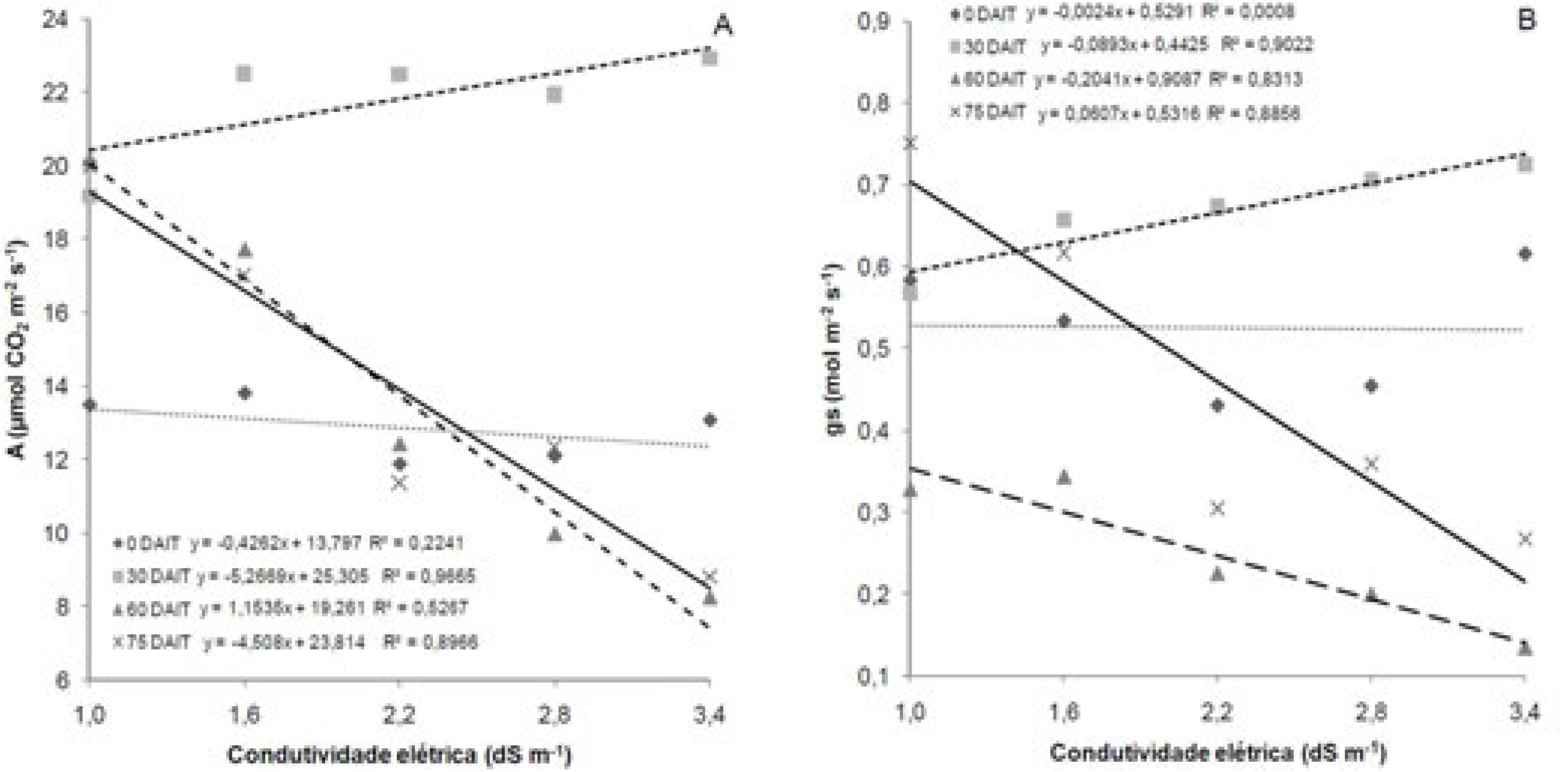
2 genotypes: Golden and UENF/Caliman

100L pots

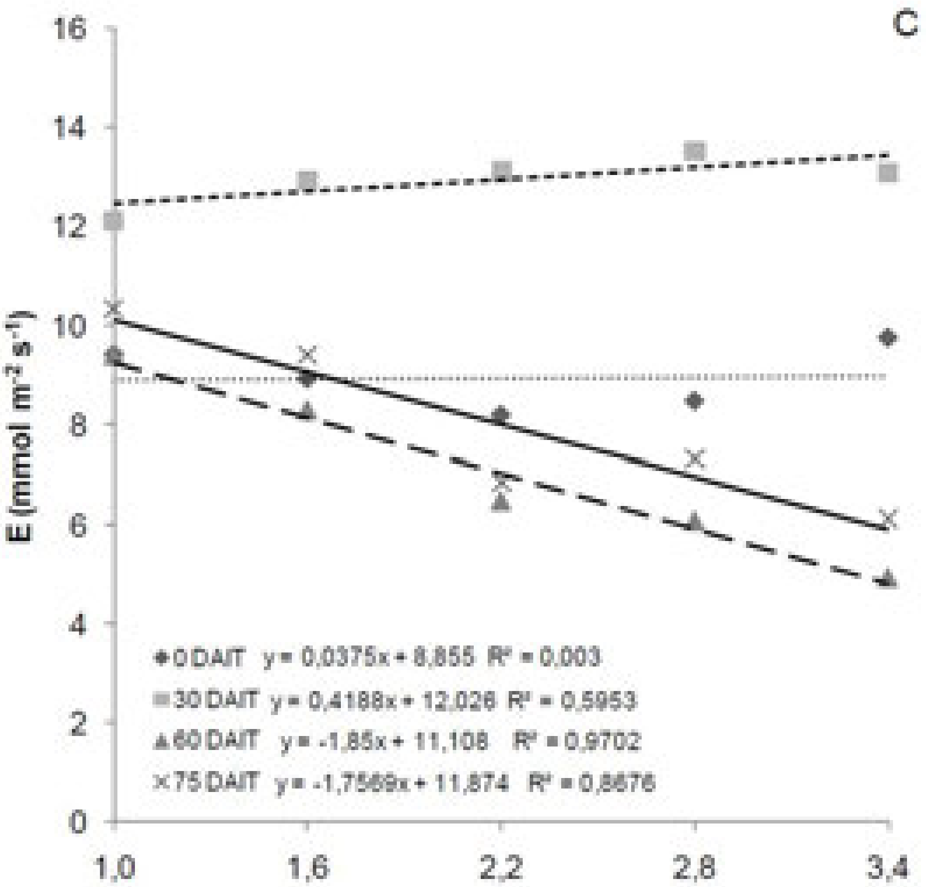
EC 1; 1.6; 2.2; 2.8; and 3.4 dS m^{-1}

		Treat. 1	Treat. 2*	Treat. 3	Treat. 4	Treat. 5
	Fertilizers (g)	x 0.5	x 1	x 1.5	x 2	x 2.5
Solution A	Urea	23.7	47.5	71.3	95.1	118.8
	MAP	11.8	23.6	35.4	47.3	59.1
	K_2SO_4	29.6	59.3	88.9	118.6	148.3
	$MgSO_4$	29.6	59.2	88.8	118.4	148
	Micronutrients	3.5	7.0	10.5	14	17.5
	CE (dS m^{-1})	**1.0**	**1.6**	**2.2**	**2.8**	**3.4**
Solution B	$Ca(NO_3)_2$	56.2	112.4	168.6	224.8	281
	CE (dS m^{-1})	**1.0**	**1.5**	**2.0**	**2.6**	**3.2**

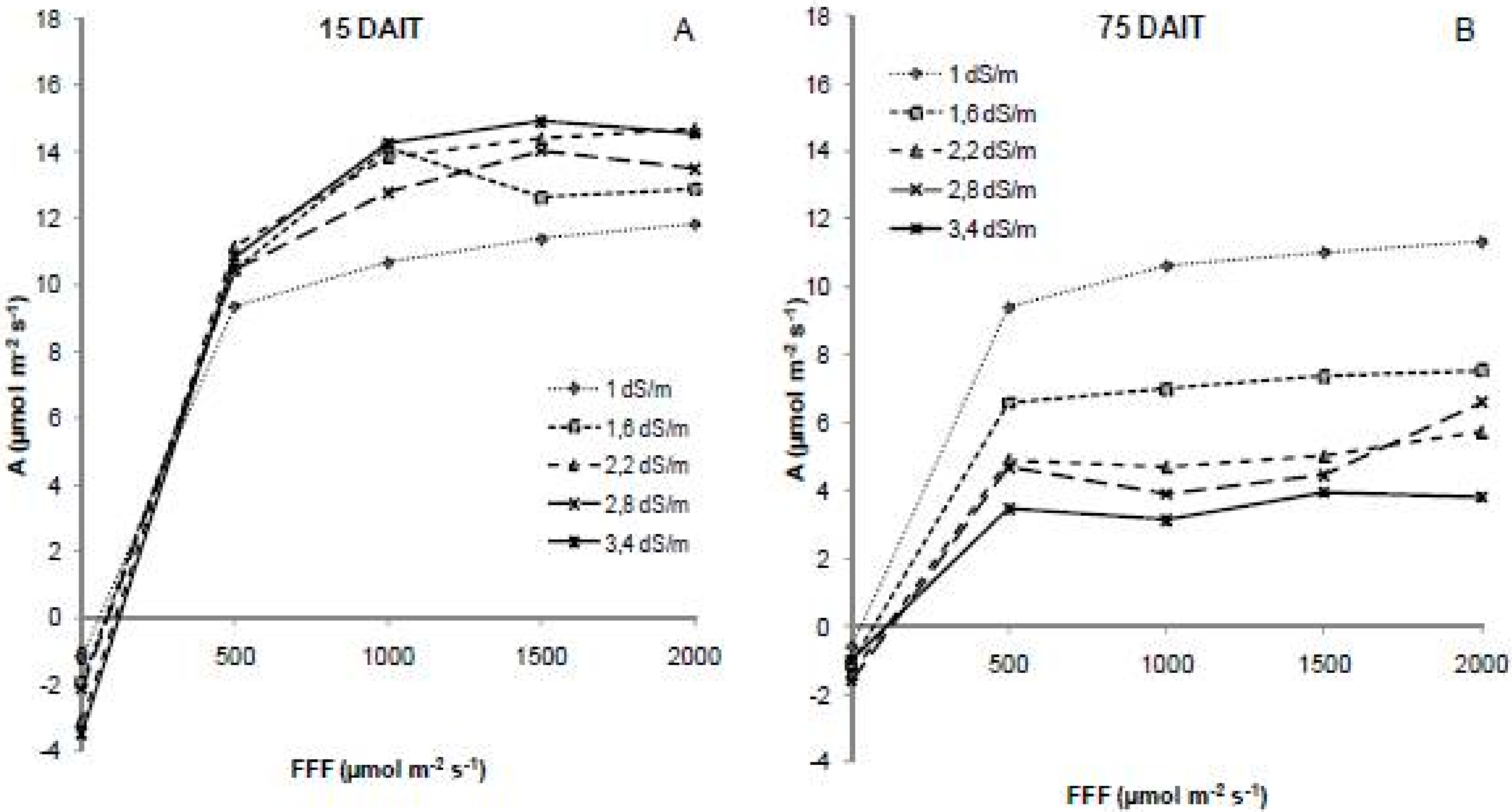
Maximum 3 L each treatment per day per plant. After each nutrient solution were applied 1.5 to 3L water in each plant per day; 3 times per day)

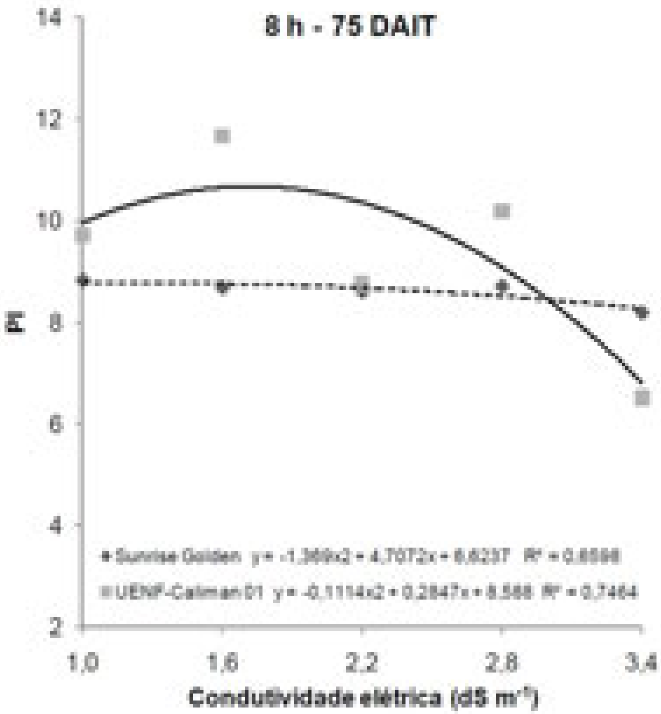


A
A (µmol CO2 m-2 s-1)
0 DAIT y = -0,4262x + 13,797 R² = 0,2241
30 DAIT y = -5,2669x + 25,305 R² = 0,9665
60 DAIT y = 1,1536x + 19,261 R² = 0,5267
75 DAIT y = -4,608x + 23,814 R² = 0,8966
Condutividade elétrica (dS m-1)
B
gs (mol m-2 s-1)
0 DAIT y = -0,0024x + 0,5291 R² = 0,0008
30 DAIT y = -0,0893x + 0,4425 R² = 0,9022
60 DAIT y = -0,2041x + 0,9087 R² = 0,8313
75 DAIT y = 0,0607x + 0,5316 R² = 0,8856
Condutividade elétrica (dS m-1)

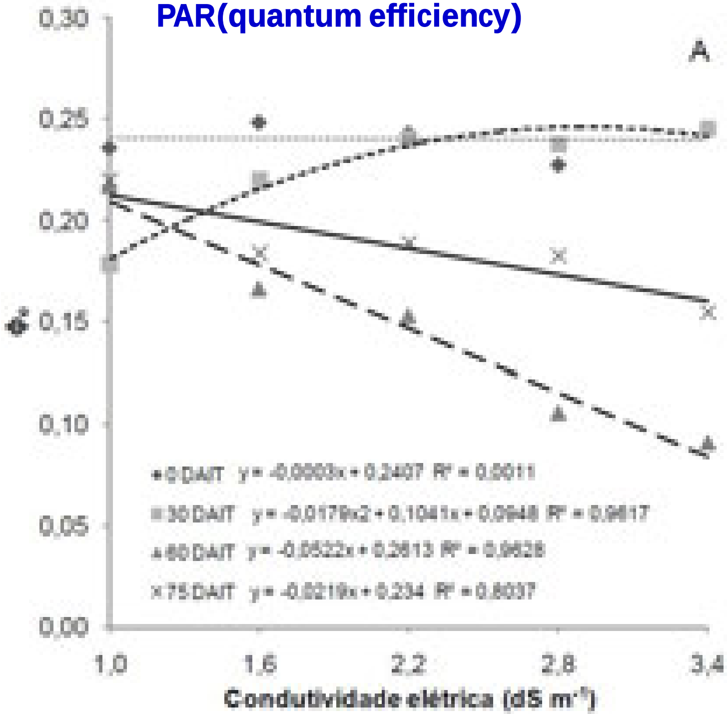


C
E (mmol m⁻² s⁻¹)
16
14
12
10
8
6
4
2
0
1,0
1,6
2,2
2,8
3,4
0 DAIT y = 0,0375x + 8,855 R² = 0,003
30 DAIT y = 0,4188x + 12,026 R² = 0,5953
60 DAIT y = -1,85x + 11,108 R² = 0,9702
75 DAIT y = -1,7569x + 11,874 R² = 0,8676


15 DAIT
A
75 DAIT
B
A (µmol m-2 s-1)
FFF (µmol m-2 s-1)
1 dS/m
1,6 dS/m
2,2 dS/m
2,8 dS/m
3,4 dS/m
18
16
14
12
10
8
6
4
2
0
-2
-4
500
1000
1500
2000



Φe = is the initial slope of the light response curve ETR versus PAR(quantum efficiency)

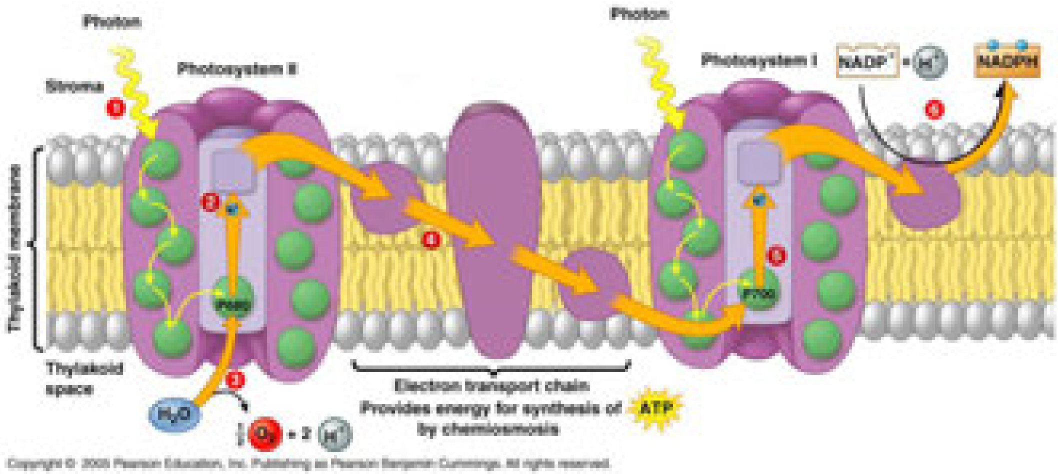


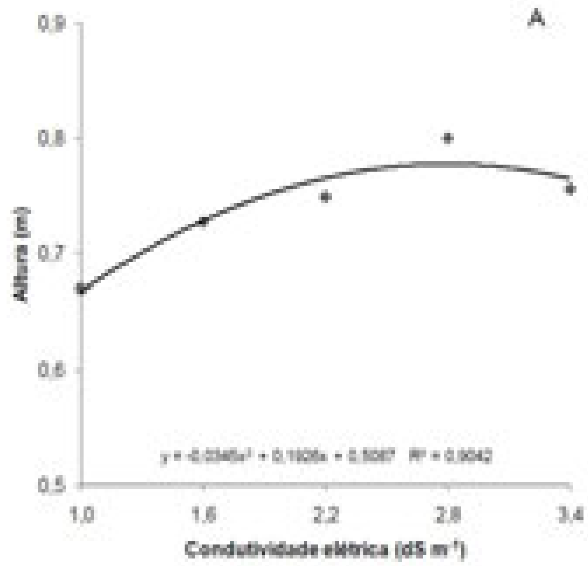
PI=(RC/ABS) x (TR/DI) x (ET/(TR-ET))

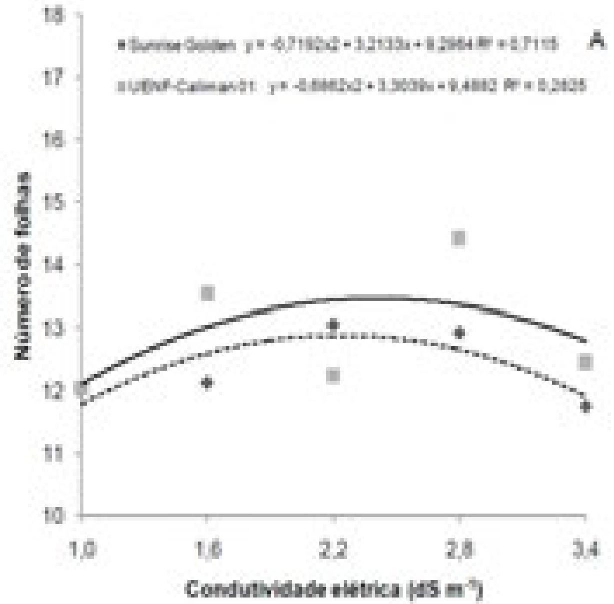
(RC/ABS): Active RC density on a Chl basis

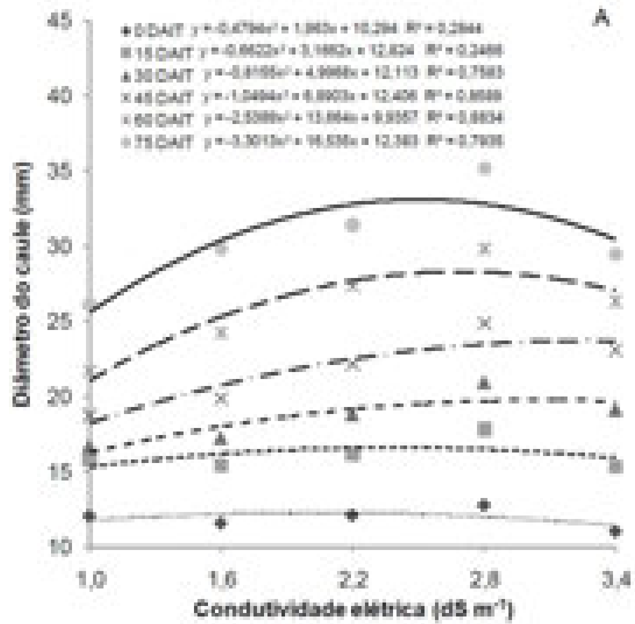
(F_V/F_0): Performance due to trapping probability $\boldsymbol{F_v/F_0=TR/DI}$

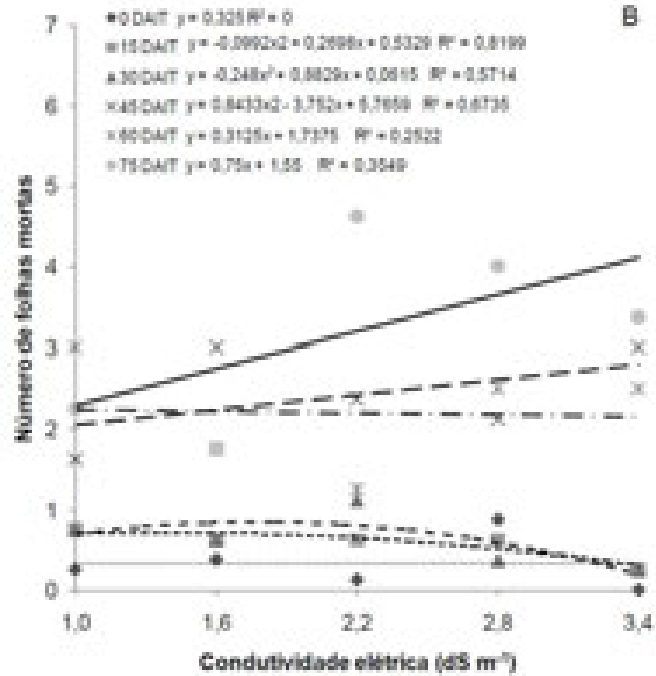
(ET/(TR-ET): Performance due to electron-transport probability

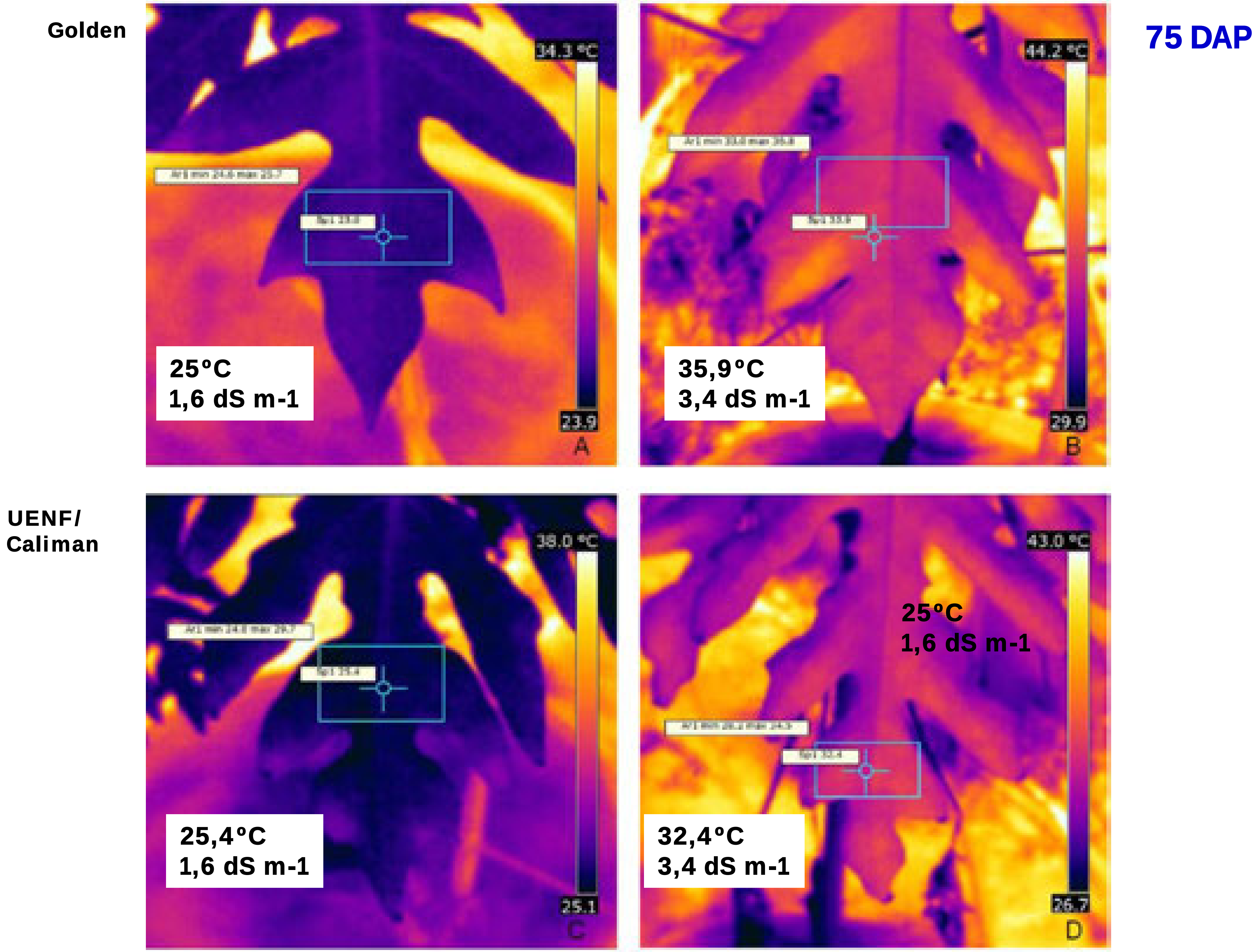



A
Altura (m)
0,9
0,8
0,7
0,6
0,5
1,0
1,6
2,2
2,8
3,4
Condutividade elétrica (dS m-1)


A
Sunrise Golden
UENF-Caliman 01
Número de folhas
18
17
16
15
14
13
12
11
10
1,0
1,6
2,2
2,8
3,4
Condutividade elétrica (dS m-1)


A
0 DAIT
15 DAIT
30 DAIT
45 DAIT
60 DAIT
75 DAIT
Diâmetro do caule (mm)
45
40
35
30
25
20
15
10
1,0
1,6
2,2
2,8
3,4
Condutividade elétrica (dS m-1)


B
0 DAIT
15 DAIT
30 DAIT
45 DAIT
60 DAIT
75 DAIT
Número de folhas mortas
7
6
5
4
3
2
1
0
1,0
1,6
2,2
2,8
3,4
Condutividade elétrica (dS m-1)


Golden
75 DAP
34.3 °C
23.9
A
25°C
1,6 dS m-1
44.2 °C
29.9
B
35,9°C
3,4 dS m-1
UENF/
Caliman
38.0 °C
25.1
C
25,4°C
1,6 dS m-1
43.0 °C
26.7
D
25°C
1,6 dS m-1
32,4°C
3,4 dS m-1

Relationships between sap-flow measurements, whole-canopy transpiration, and reference evapotranspiration in field-grown papaya (*carica papaya* l.)

Summer: (clear sky, during 4 days)

PPF_{max}: 2400 μmol m^{-2} s^{-1}

T_{max}: 38ºC

VPD_{max}: 4 kPa

Winter: (clear sky during 4 days)

PPF_{max}: 1400 μmol m^{-2} s^{-1}

T_{max}: 33ºC

VPD_{max}: 3.5 kPa

The crop was irrigated with a drip/fertigation system providing supplemental irrigation of **10** (winter) and **16 L per plant per day** (summer)

Under the environmental conditions evaluated :
(4 sunny days)

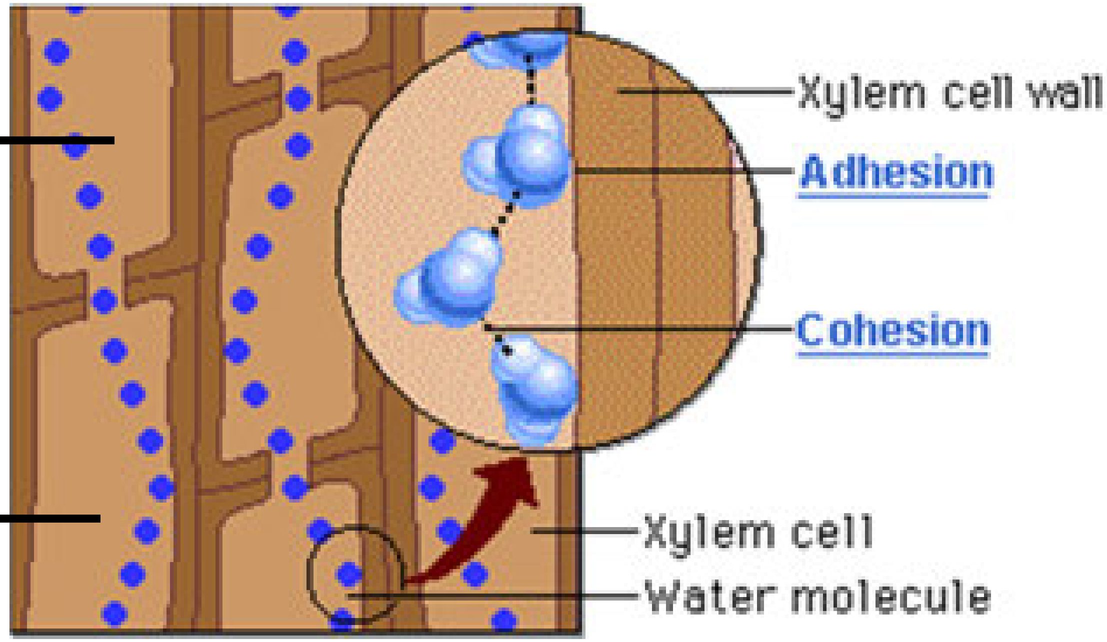
Winter:
Maximum vapor pressure deficit (VPD_{air})=3.5 kPa
Air maximum temperature of 33°C
Maximum PPF: 2400 μmol m^{-2} s^{-1}

Summer
Maximum VPD_{air}=4.0 kPa
Air maximum temperature of 38°C
Maximum PPF : 1400 μmol m^{-2} s^{-1}

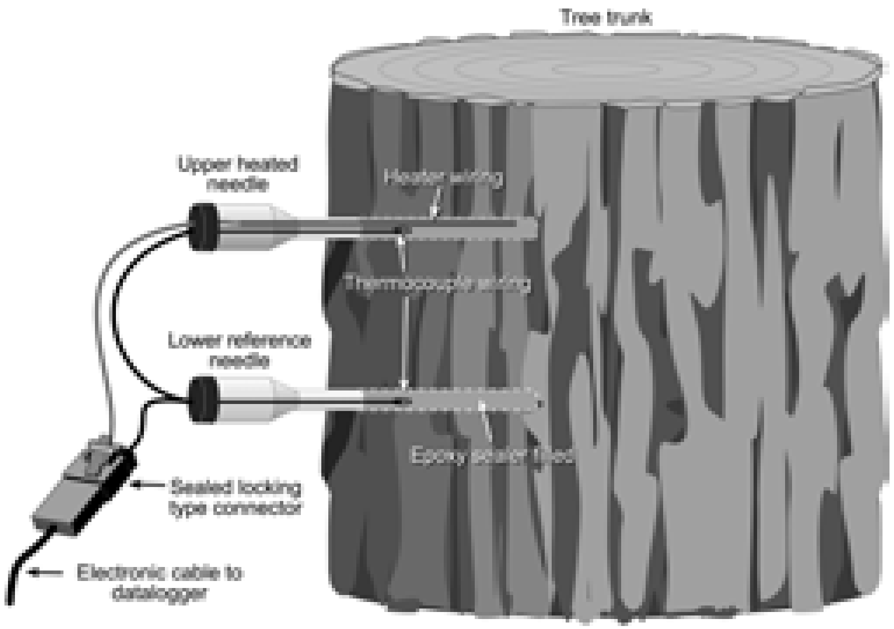
Leaf area each plant
5 months old
Winter :3.5m^2
Summer: 4 m^2

A

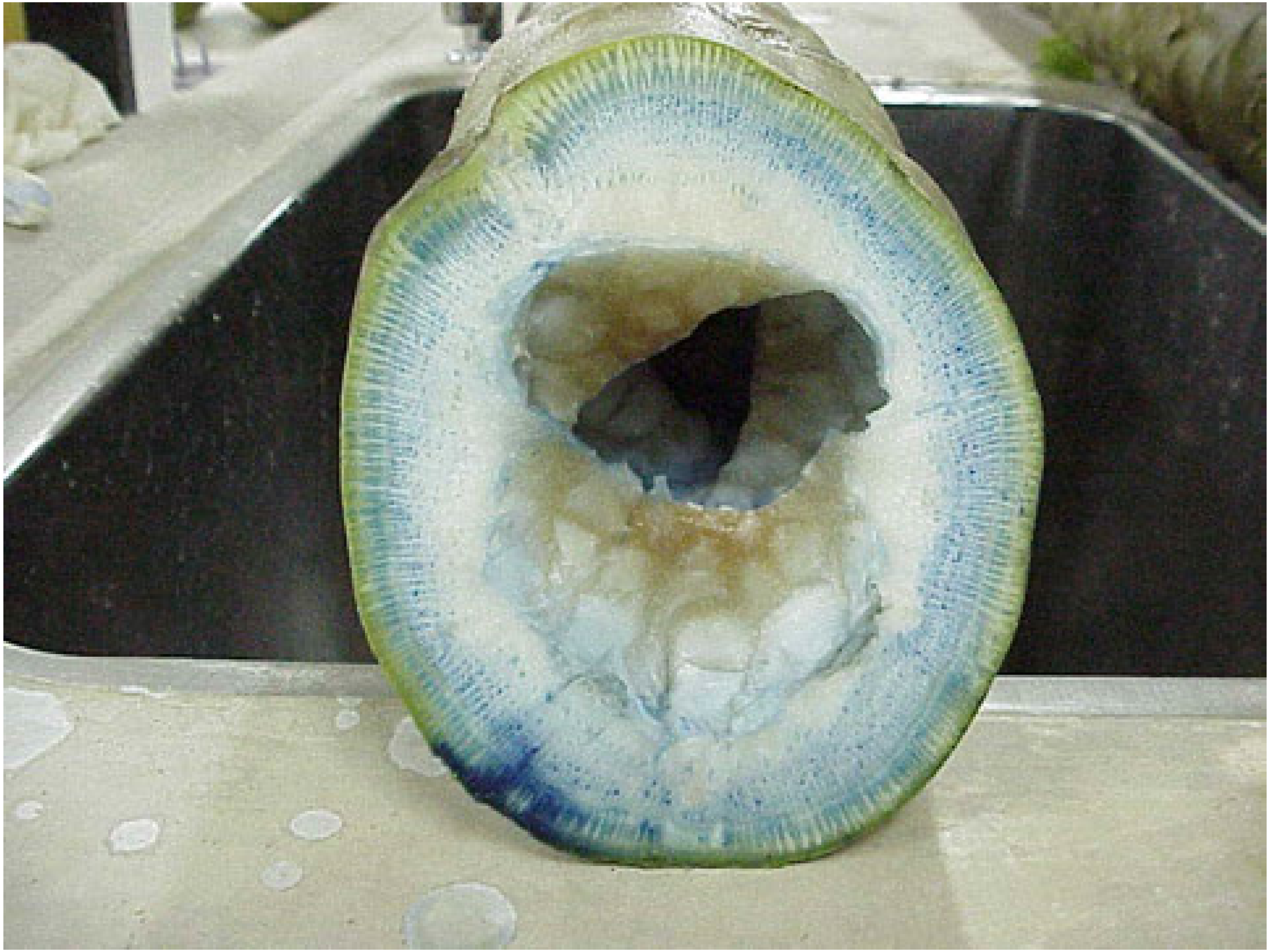
B

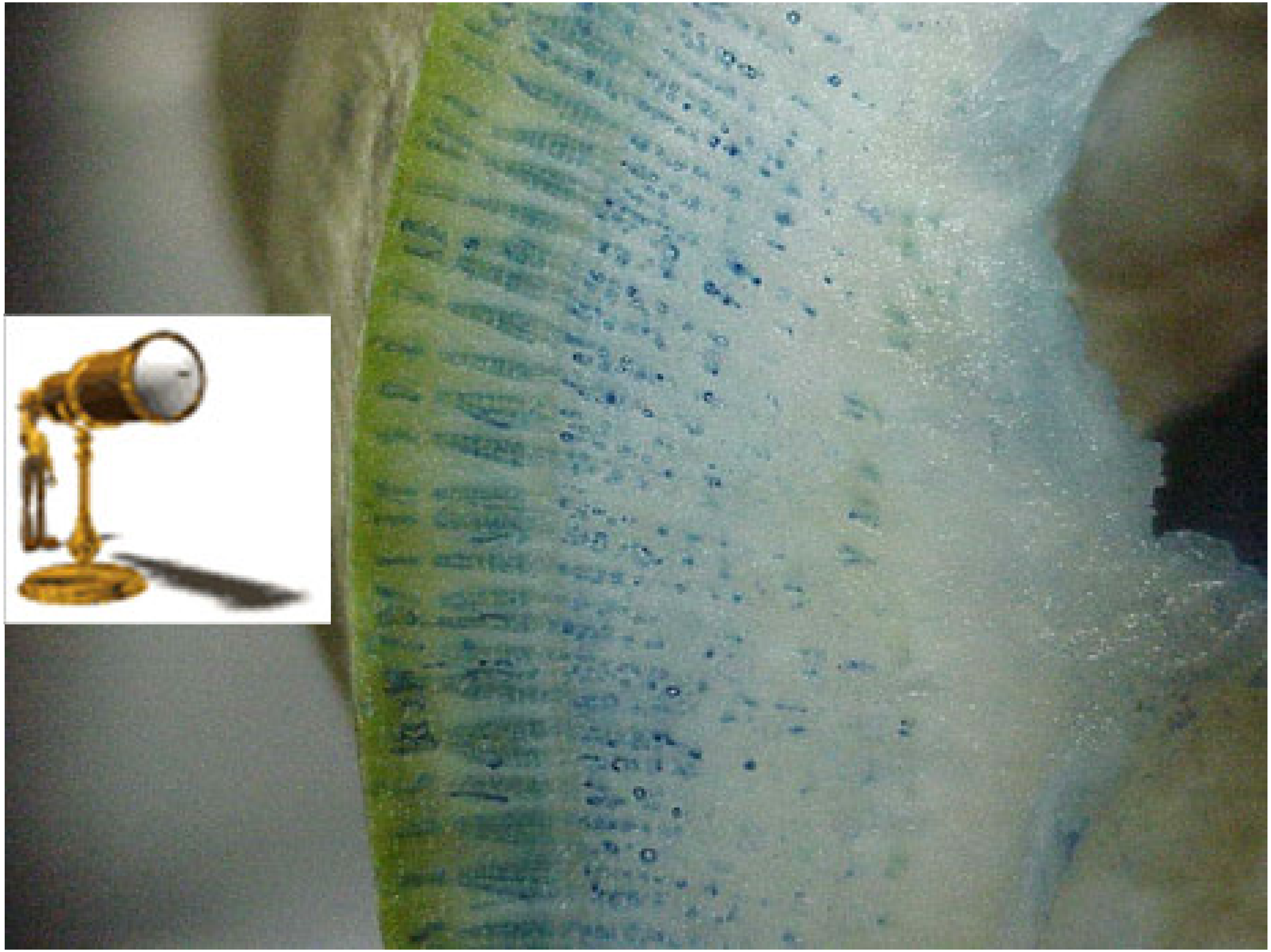


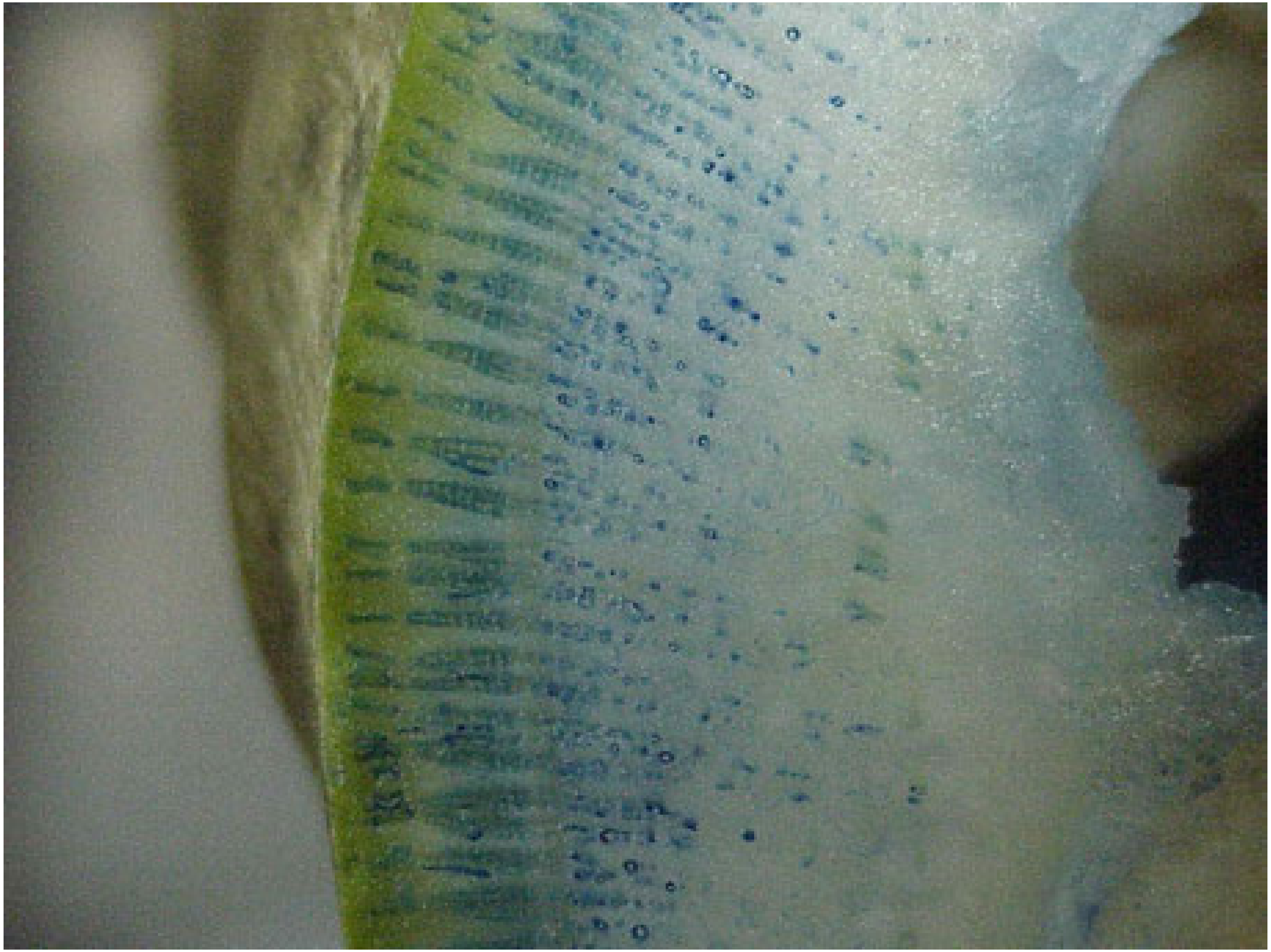
Xylem cell wall
Adhesion
Cohesion
Xylem cell
Water molecule

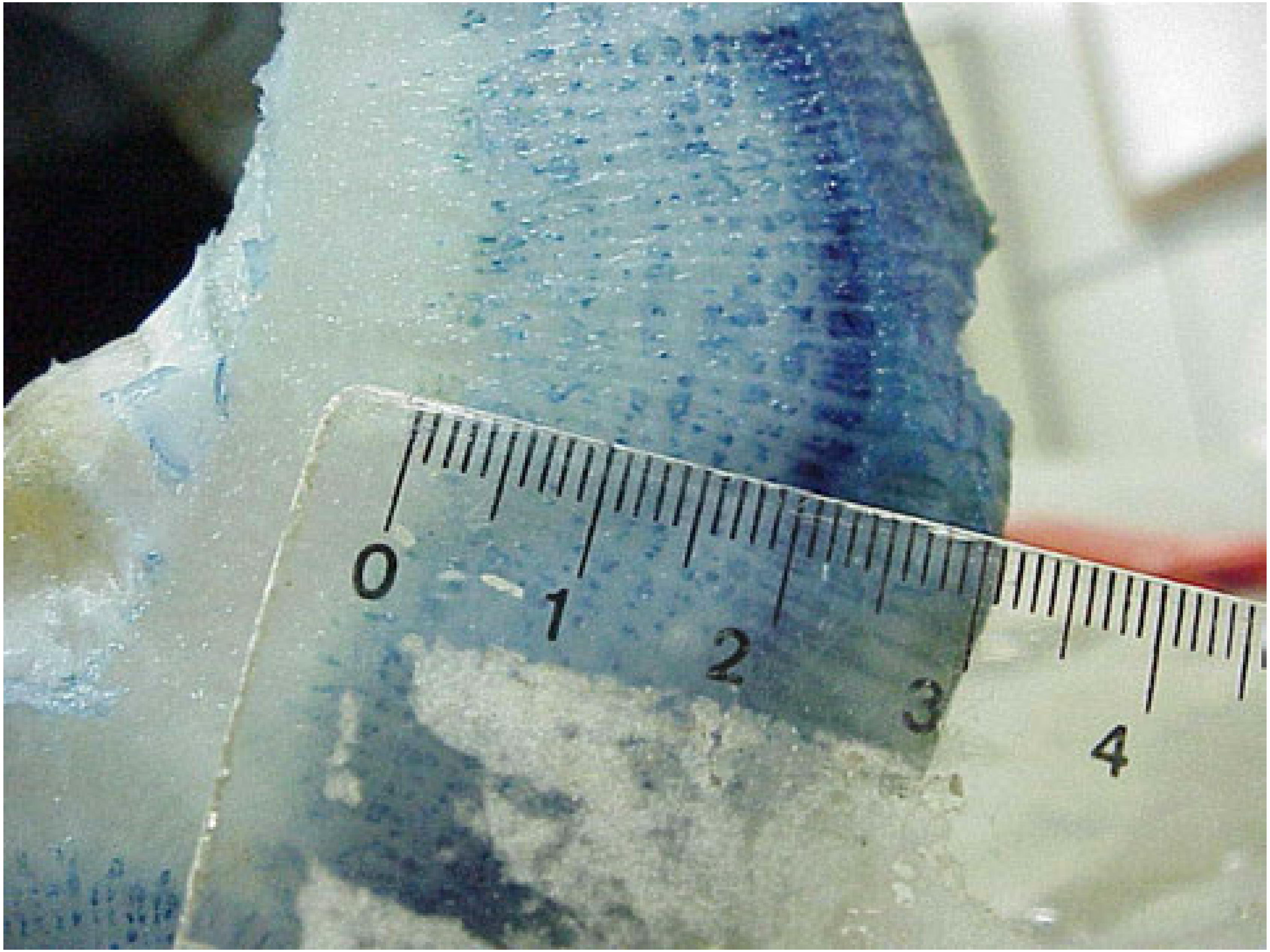


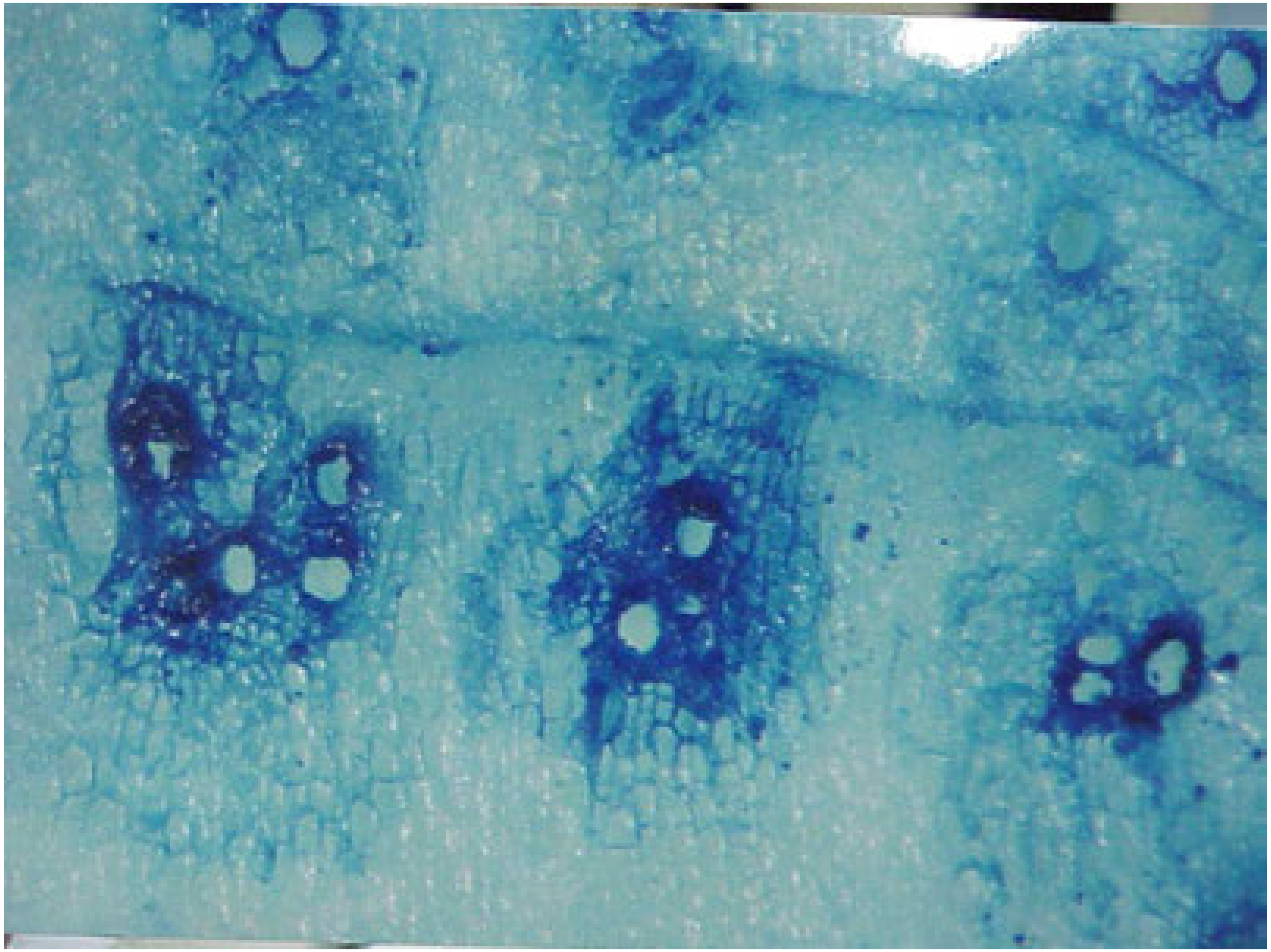
Tree trunk
Upper heated needle
Heater wiring
Thermocouple wiring
Lower reference needle
Sealed locking type connector
Electronic cable to datalogger

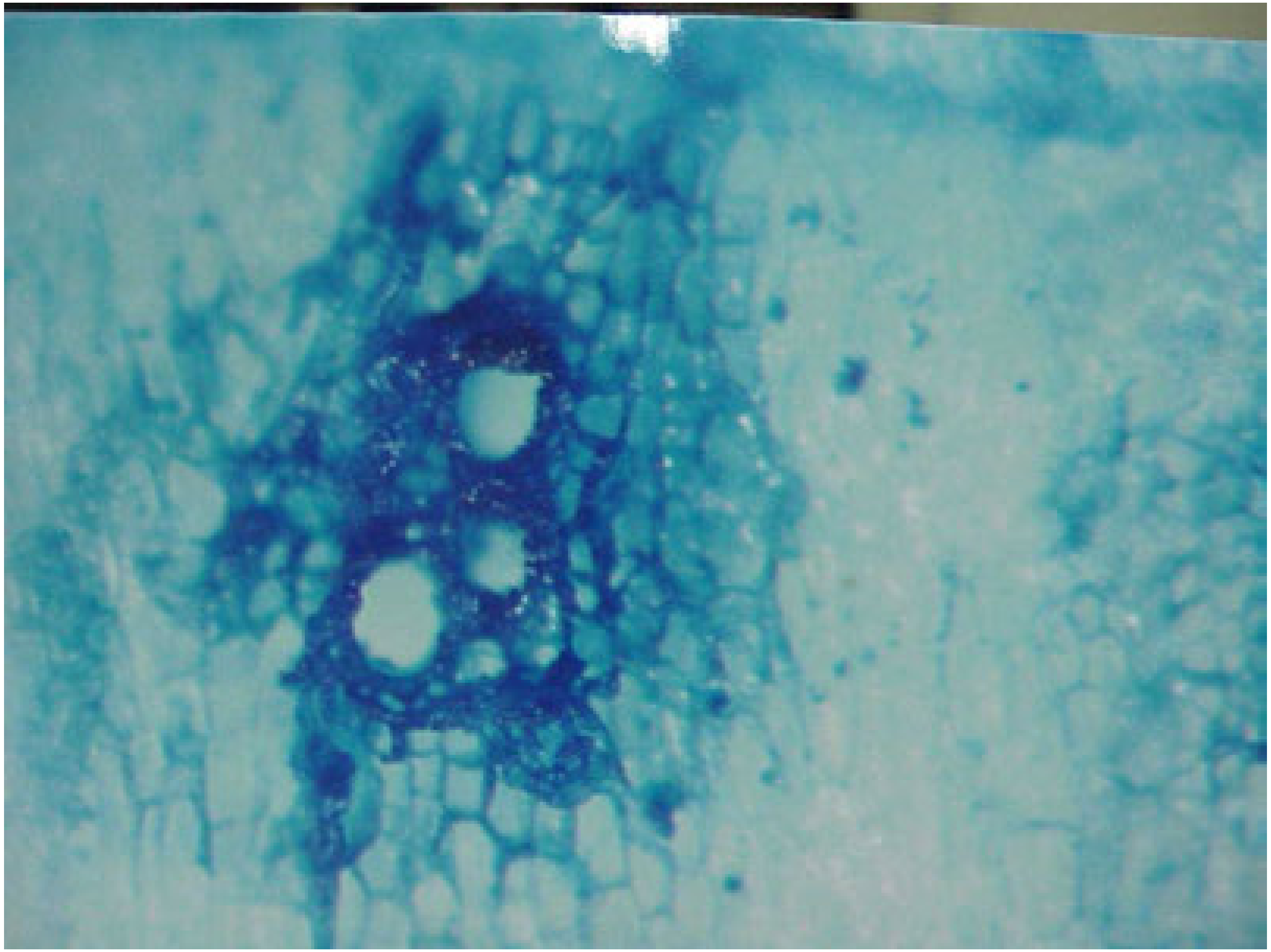


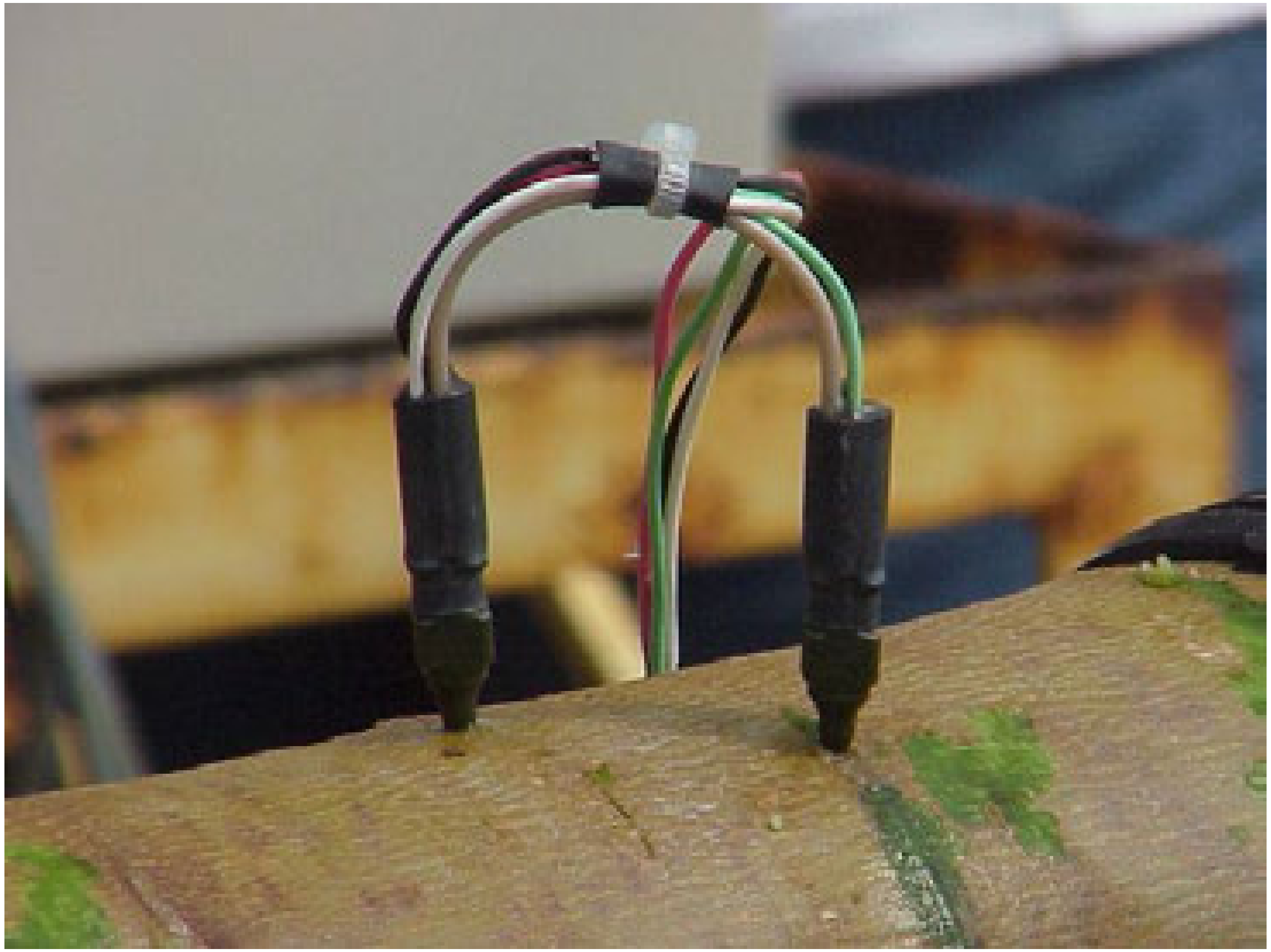




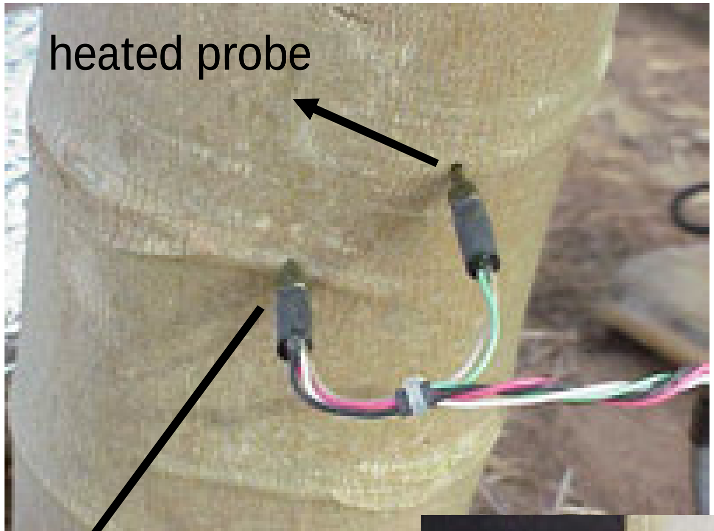

0
1
2
3
4

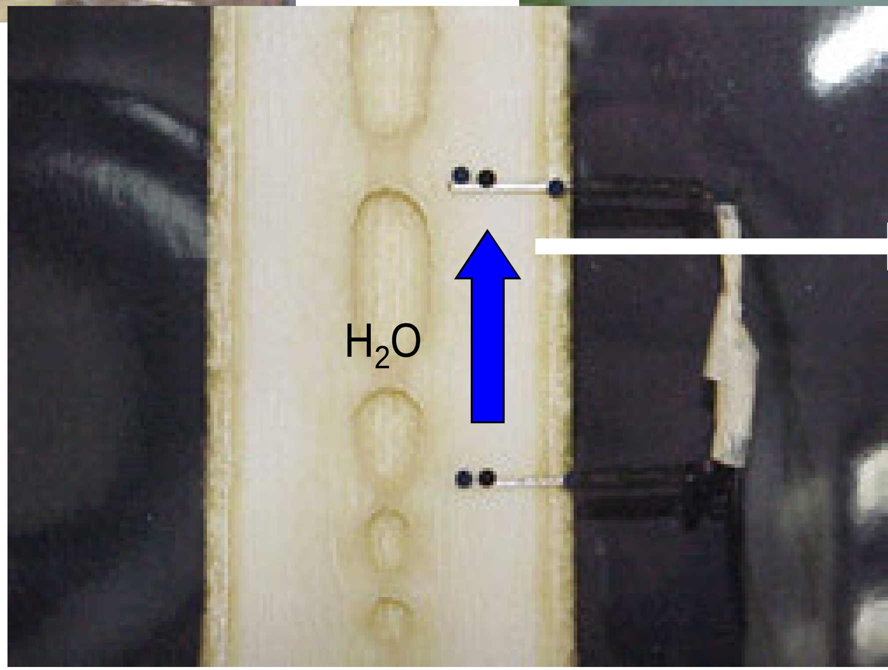






Effects on sap flow

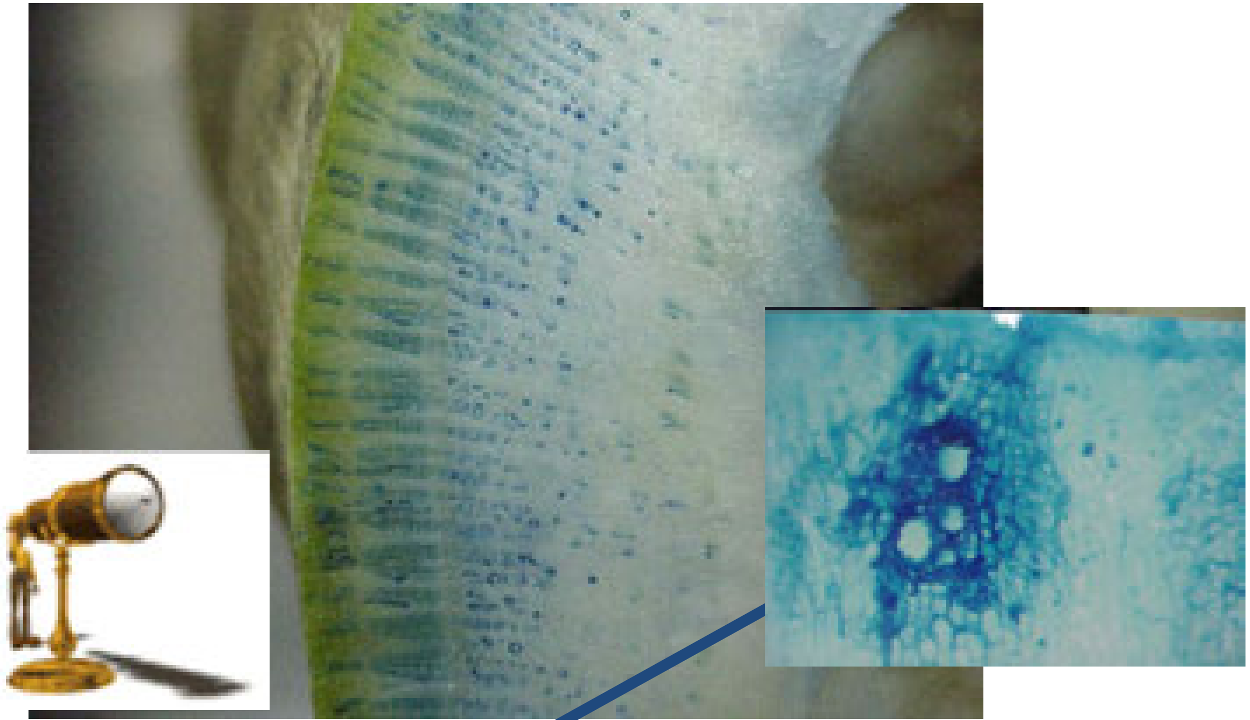




non-heated probe

Sap flow measure
differences
between
heated and
non-heated probe

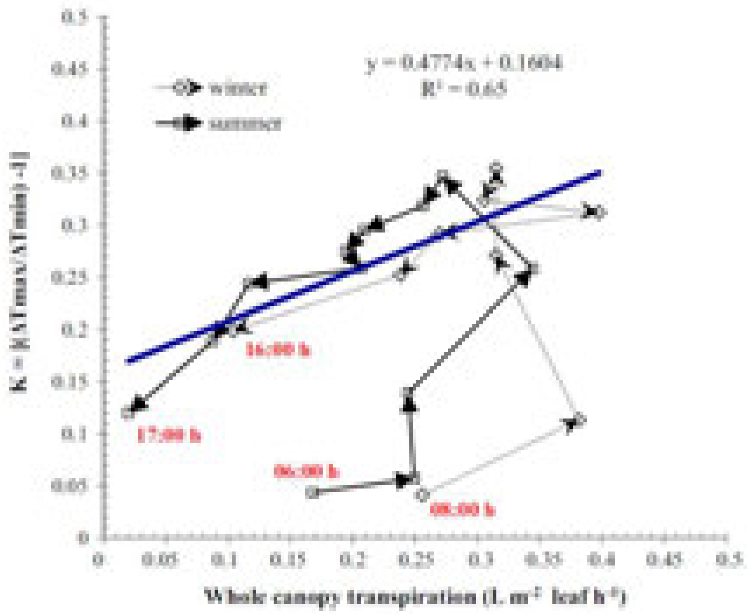
Water reduce
temperature



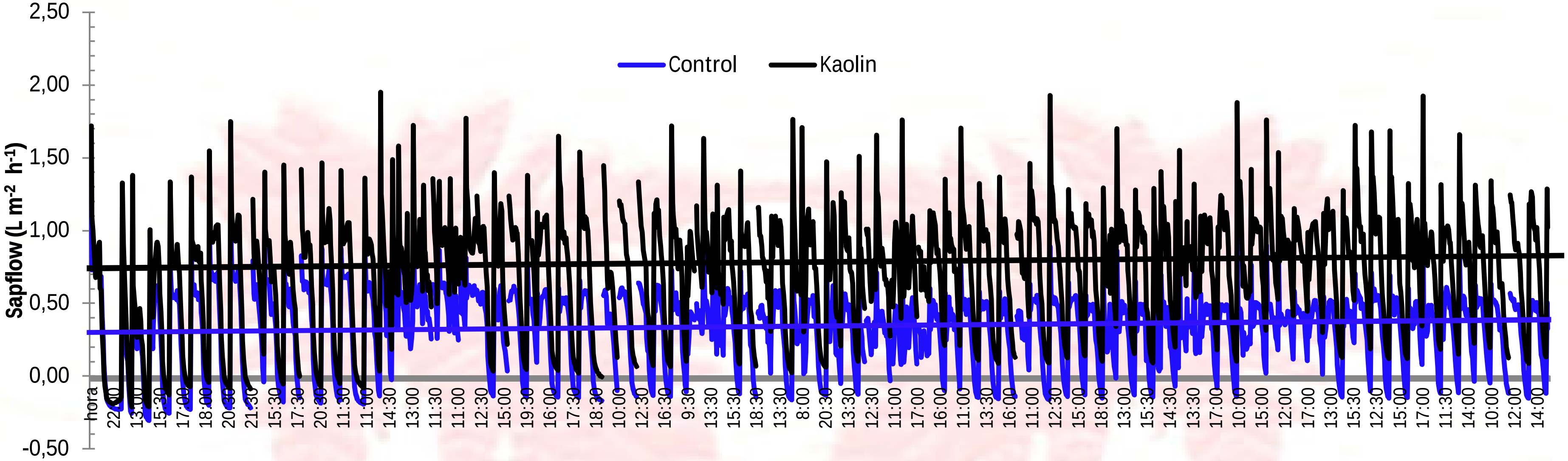
Xylem vessel

~~[reviewer1]Is night time relevant?~~

Fig. 5 Relationship between mean hourly whole-canopy transpiration and the xylem sap flow heat coefficient (K) in 'Gran Golden' papaya during four days in winter and summer. Arrows indicate the chronological progression during the day. Whole canopy transpiration data excluded from the regression were 8:00 to 9:00 h in winter related to dew on the leaf surfaces and Mylar chamber and lag phase in summer from 6:00 to 8:00 h



K is the heat coefficient:
ΔT_m : the maximum temperature difference (°C) between sensors in active xylem (night time), and ΔT is the temperature difference (°C) between sensors in active xylem



May to July (winter dry season)(104days)

Plant leaf area: **5m²**

Kaolin particles:
0.70 L h m^{-2} x $5m^2$ = 3.5 L h^{-1} $plant^{-1}$ x 8h = **28 L H_2O $plant^{-1}$ day^{-1}**

Control:
0.32 L h m^{-2} = 1.60 L h plant x 8h = **12.8 L H_2O $plant^{-1}$ day^{-1}**

Maximum light = 2300µmol m^{-2} s^{-1} = 1000 W m^{-2}

Mycorrhizal fungi effects on papaya productivity

The beneficial effects of arbuscular mycorrhizal (AM) fungi in the plant kingdom and agricultural cropping systems are well documented, and include increased P, water, and nutrient uptake as well as improved pest resistance (Harley and Smith, 1983; Bethlenfalvay and Linderman, 1992)

Arbuscular mycorrhizal fungi colonize papaya under natural conditions. Papaya appears to be very dependent on AM since plants in sterilized soil, as compared to inoculated, showed poor growth and particularly P uptake (Habte, 2000)

Mohandas (1992) reported that AM inoculation of papaya seedlings increased growth, P concentration and acid phosphatase activity in leaves

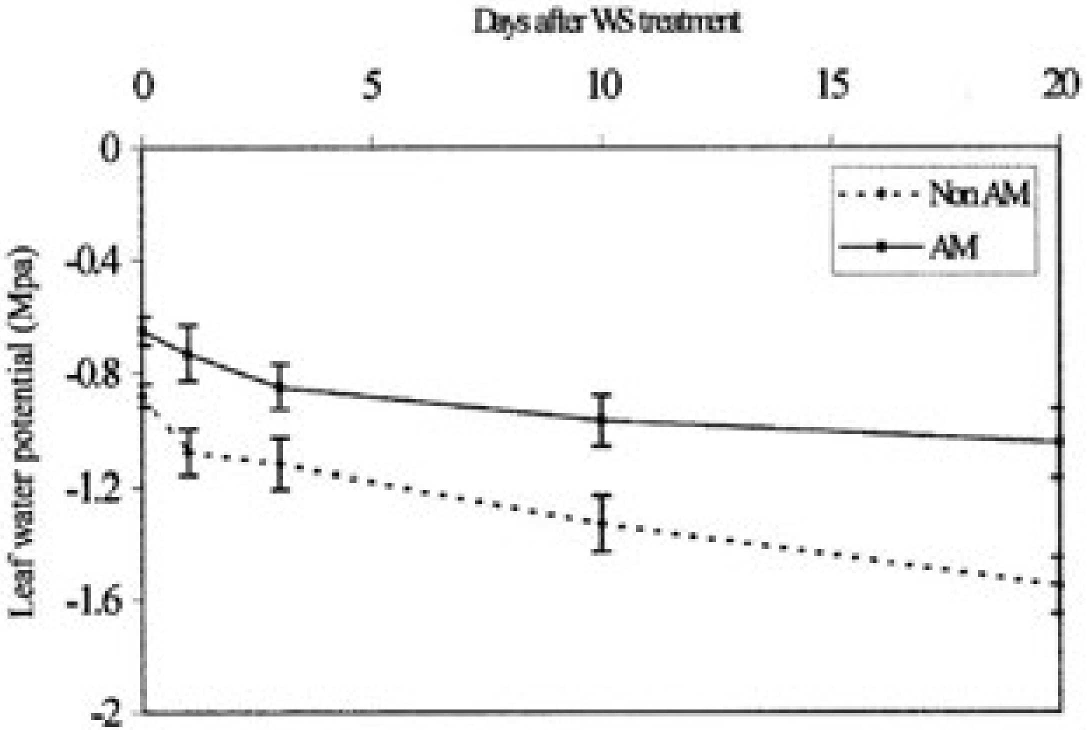


Fig. 1 Leaf water potential of papaya trees inoculated with an arbuscular mycorrhizal (*AM*) fungus, *Gigaspora margarita*, and non-inoculated (*Non AM*) trees during period of water stress (*WS*). *Vertical bars* indicate SE ($n = 3$)

Table 1 Biomass yield (g) of papaya trees inoculated with an arbuscular mycorrhizal (*AM*) fungus, *Gigaspora margarita*, and non-inoculated (*Non AM*) trees under irrigated and water-stress conditions. The data are means ± standard error (SE) ($n=3$) (*RFW* root fresh weight, *TFW* total fresh weight)

Treatment	Biomass yield			
	Irrigated		Water stressed	
	RFW	TFW	RFW	TFW
Non AM	55.2 ± 5.8	99.4 ± 9.8	44.0 ± 5.4	75.8 ± 7.3
AM	85.9 ± 6.5	141.1 ± 10.5	66.4 ± 4.9	119.6 ± 6.6

20 days of water-stress treatment

Treatments were applied 3 months after planting

Table 2 Concentrations of 1-aminocyclopropane-1-carboxylic acid (*ACC*) and ethylene in papaya roots inoculated with an arbuscular mycorrhizal (*AM*) fungus, *Gigaspora margarita*, and non-inoculated (*Non AM*) trees under irrigated and water-stress conditions. The data are means ± SE ($n=3$)

Treatment	ACC (nmol/g fresh wt.)		Ethylene (ppm)	
	Irrigated	Water stressed	Irrigated	Water stressed
Non AM	0.14 ± 0.04	0.62 ± 0.04	0.93 ± 0.04	1.41 ± 0.04
AM	0.06 ± 0.01	0.41 ± 0.04	1.35 ± 0.04	1.23 ± 0.03

20 days of water-stress treatment

Mycorrhiza establishment may result in the control of ethylene levels as one mechanism of reducing damage by water stress in papaya plants.

Besmer and Koide (1999) showed that mycorrhizal colonization can decrease ethylene concentration in flowers, which might explain the increased vase-life of cut flowers.

AM colonization may act as an inhibitor of ethylene biosynthesis by influencing ACC conversion to ethylene

Mechanical root restriction

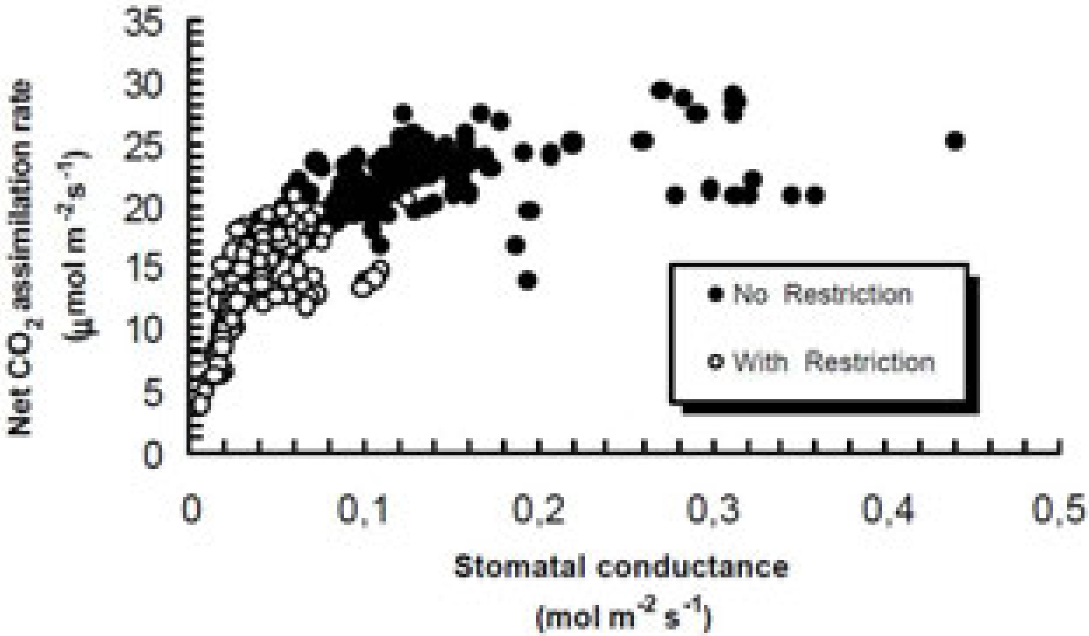


TABLE 1 - Textural class, bulk density, particle density, porosity and macroporosity of the soil in Macaé/RJ/Brazil

Horizon	B_d^z (g cm^{-3})	P_d^y (g cm^{-3})	Soil Porosity (%)	Soil Macroporosity^x (%)
A^w (sandy-loam)	1.74	2.60	33.1	13.3
B^v (clay)	1.64	2.61	37.2	7.9

B_d^z = Bulk Density, P_d^y = Particle Density, Macroporosity^x (0.1atm), (sandy-loam, 58% coarse, 15% fine sandy, 07% silt and 20% clay)^w, (clay, 25% coarse, 19% fine sandy, 08% silt and 48% clay)^v.

TABLE 4 - Net CO_2 assimilation rate (*A*), stomatal conductance (g_s), intercellular partial pressure CO_2 (c_i) and leaf temperature (T_l) of four papaya (*Carica papaya* L.) genotypes as influenced by root zone restriction in Macaé/RJ/Brazil. Determined in the third day after the irrigation.

Genotypes	A^z (μmol m^{-2} s^{-1})		g_s^z (mol m^{-2} s^{-1})		c_i^z (μL L^{-1})		T_l^z (°C)	
	NR[y]	WR[x]	NR	WR	NR	WR	NR	WR
Sunrise Solo TJ	17.1 Aa[w]	10.0 Bb	0.110 Ab	0.021 Ba	282.1 Ac	261.4 Bb	36.7 Ba	38.1 Aa
Sunrise Solo 72/12	22.0 Aa	11.5 Bb	0.226 A a	0.052 Ba	296.7 Ab	271.3 Bab	35.3 Bb	36.5 Ad
Tainung 02	22.2 Aa	12.3 Bab	0.131 Ab	0.029 Ba	309.4 Aa	276.8 Ba	36.8 Ba	37.6 Ab
Know -You 01	21.8 Aa	15.2 Ba	0.210 Aa	0.062 Ba	293.2 Abc	282.8 Aa	35.7 Bab	37.8 Aab

[z] Determined 150 days after transplanting, on third day after irrigation; Quantum flux of photons 1650.60 ± 160.90 μmol m^{-2} s^{-1}. Data collected at 9:00-11:00 AM. Air Temperature 36.90 ± 0.8°C. CO_2 concentration into chamber 360.00 ± 11.70 μL L^{-1}. Partial pressure of water vapour into chamber 3.59 ± 0.11 kPa; Soil moisture on volume basis 9.36 ± 1.73 %, [Field Capacity=11.00%]; [y] NR= Area with no restriction to root growth, [x] WR= Area with restriction of root growth ; [w] Average followed by the same small letters in columns or capital letters in the rows (for each characteristic) did not differ at the probability level of 5% ($p<0.05$) using Duncan's Multiple Range Test.

Tables

1. Total leaf number (TLN), average leaf area (ALA), length of leaf central vein (LLCV), total leaf area (TLA) of four papaya (*Carica papaya* L.) genotypes as influenced by root zone restriction in Macaé/RJ/Brazil.

	TLN[z]		ALA[x] (m^2)		LLCV[y] (m)		TLA[x] (m^2)	
Genotypes	NR[v]	WR[w]	NR	WR	NR	WR	NR	WR
Sunrise Solo TJ	24.8 Aa	14.3Ba[u]	0.18Ab	0.15Bb	0.40Ab	0.35Bc	4.55Ab	2.09Bb
Sunrise Solo 72/12	22.0 Aa	17.0Ba	0.20Ab	0.17Bb	0.41Ab	0.38Bb	4.46Ab	2.88Ba
Tainung 02	25.5 Aa	10.7Bb	0.21Ab	0.15Bb	0.42Ab	0.34Bc	5.25Ab	1.61Bb
Know -You	24.3 Aa	16.8Ba	0.27Aa	0.22Ba	0.49Aa	0.44 Ba	6.52Aa	3.73Ba

[z] Determined at fifteen months after transplant.

[y] Determined by millimeter ruler.

[x] Determined by equation, fifteen months after transplant: Log LA= 0.315 + 1.85 Log LLCV, R^2=0.898 were LA = Leaf Area and LLCV = length of leaf central vein.

[w] WR= Area with restriction on root growth system. Average effective deepness with 0.35 ± 0.05 m, with 4.12 ± 0.2 MPa of the maximum force.

[v] NR= Area with no restriction to root growth. Minimum effective deepness with 0.60 m, that received a force lower than 2.30 MPa for penetration. Effective deepness was determined using penetrographer (SOILCONTROL, Santo Amaro, SP, Brazil).

[u] In the horizontal, average followed by the same capital letters for each analyzed characteristic are not significantly different at the 5% probability level using the Duncan test. In the vertical, average followed by the same small letters for each analyzed characteristic are not significantly different at the 5% probability level using the Duncan test.

Tables

1. Total leaf number (TLN), average leaf area (ALA), length of leaf central vein (LLCV), total leaf area (TLA) of four papaya (*Carica papaya* L.) genotypes as influenced by root zone restriction in Macaé/RJ/Brazil.

Genotypes	TLN[z]		ALA[x] (m^2)		LLCV[y] (m)		TLA[x] (m^2)	
	NR[v]	WR[w]	NR	WR	NR	WR	NR	WR
Sunrise Solo TJ	24.8 Aa	14.3Ba[u]	0.18Ab	0.15Bb	0.40Ab	0.35Bc	4.55Ab	2.09Bb
Sunrise Solo 72/12	22.0 Aa	17.0Ba	0.20Ab	0.17Bb	0.41Ab	0.38Bb	4.46Ab	2.88Ba
Tainung 02	25.5 Aa	10.7Bb	0.21Ab	0.15Bb	0.42Ab	0.34Bc	5.25Ab	1.61Bb
Know -You	24.3 Aa	16.8Ba	0.27Aa	0.22Ba	0.49Aa	0.44 Ba	6.52Aa	3.73Ba

[z] Determined at fifteen months after transplant.

[y] Determined by millimeter ruler.

[x] Determined by equation, fifteen months after transplant: Log LA= 0.315 + 1.85 Log LLCV, R^2=0.898 were LA = Leaf Area and LLCV = length of leaf central vein.

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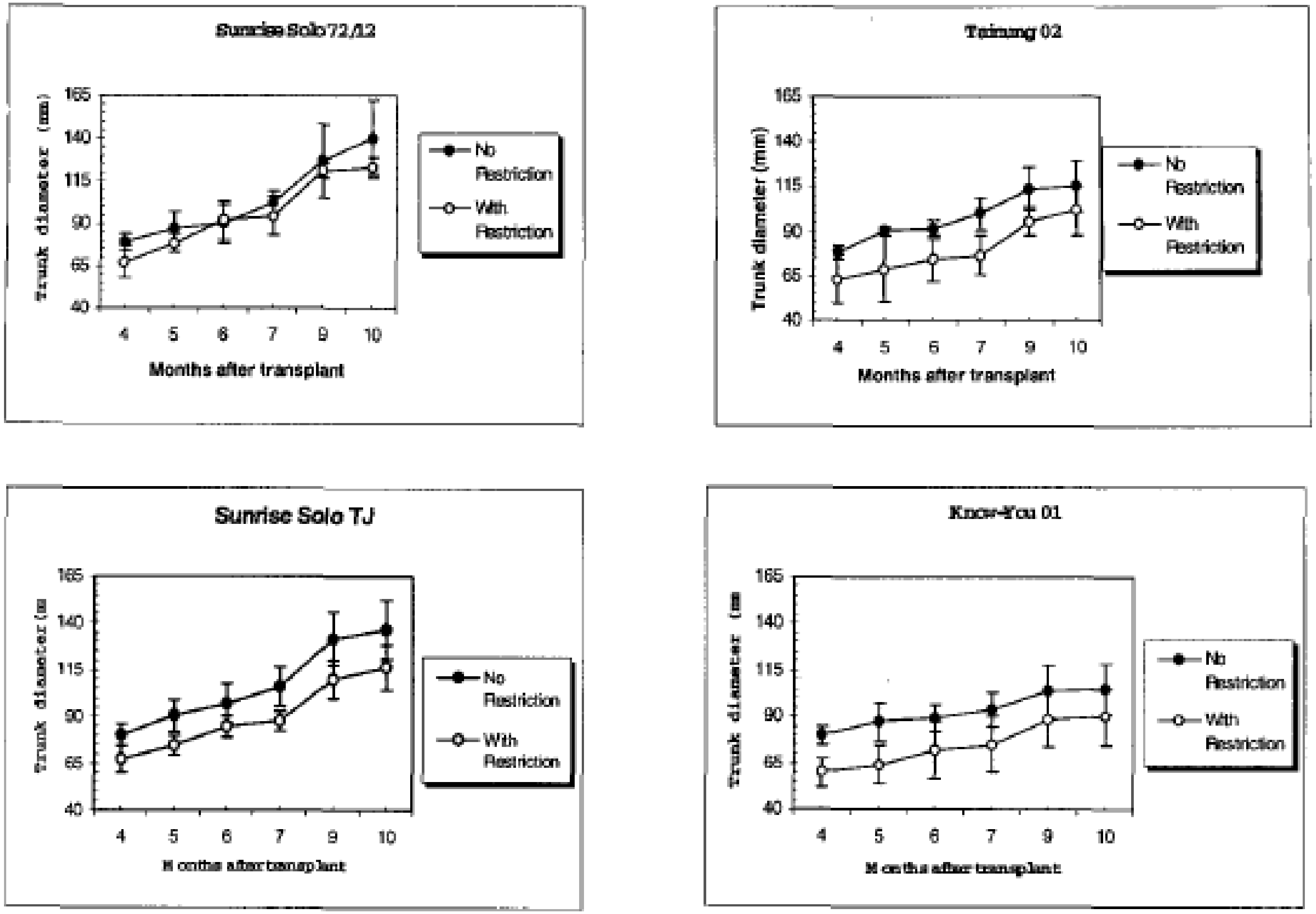
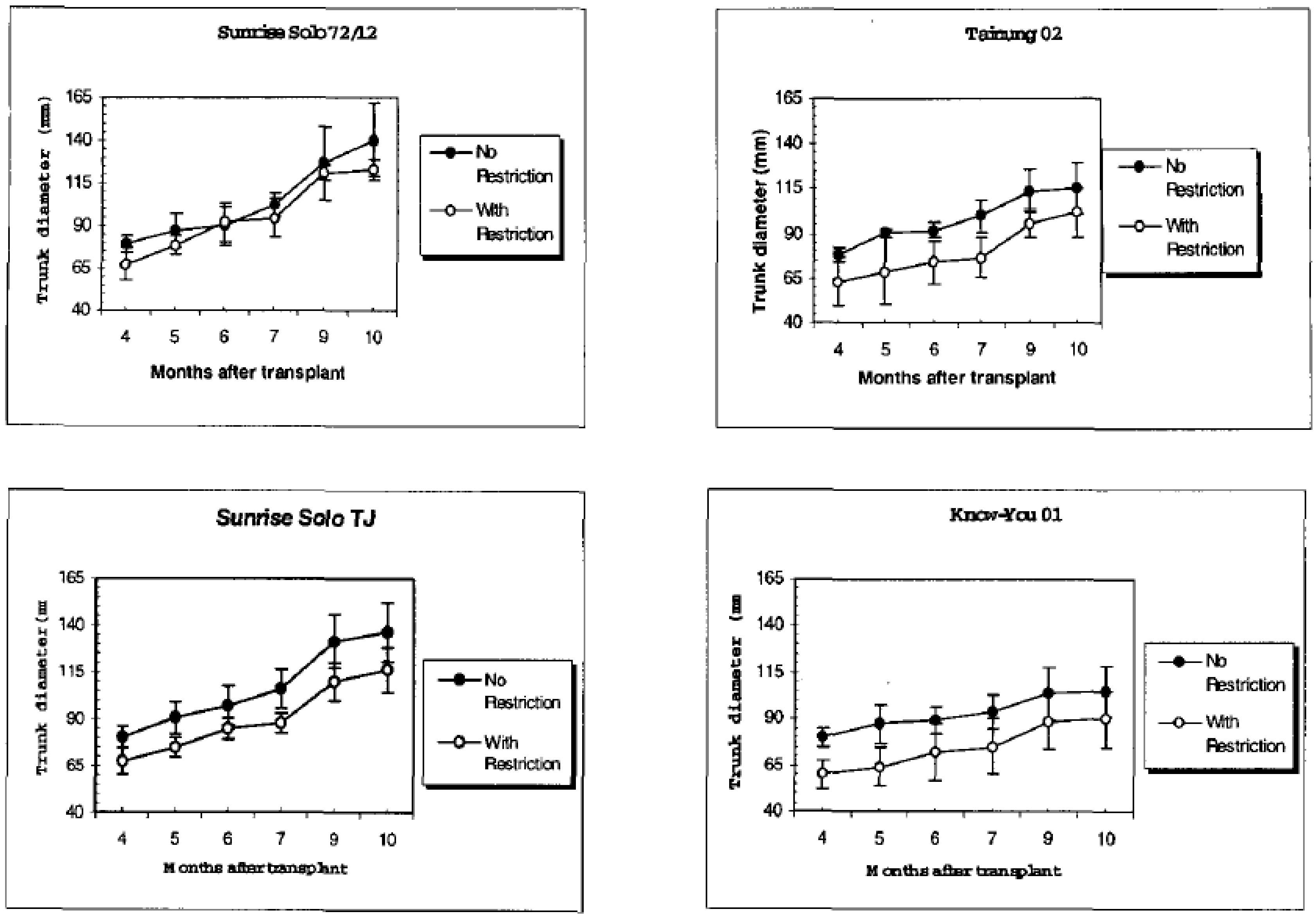
[u] In the horizontal, average followed by the same capital letters for each analyzed characteristic are not significantly different at the 5% probability level using the Duncan test. In the vertical, average followed by the same small letters for each analyzed characteristic are not significantly different at the 5% probability level using the Duncan test.



2. Seasonal changes in trunk diameter of four papaya genotypes as affected by root zone restriction in Macaé/RJ/Brazil. Vertical bars indicate standard error (n=4).



2. Seasonal changes in trunk diameter of four papaya genotypes as affected by root zone restriction in Macaé/RJ/Brazil. Vertical bars indicate standard error (n=4).

Wind

Table 1. Single leaf area, leaf expansion rate, and root extension rate of 'Tainung 2' and 'Sunrise' papaya plants exposed to or fully protected from ambient winds at the end of 3-week experiments conducted 3 to 24 May 2009 (mean wind speed = 2.37 $m \cdot s^{-1}$), 4 to 25 Sept. 2009 (mean wind speed = 3.06 $m \cdot s^{-1}$), and 6 to 27 Jan. 2010 (mean wind speed = 3.77 $m \cdot s^{-1}$).[z]

Response variable	Wind treatment: Protected	Wind treatment: Exposed	P
	Expt. 1		
Leaf area (cm^2)	199	196	0.6087
Leaf expansion ($mm \cdot d^{-1}$)	6.83	5.85	0.0665
Root extension ($mm \cdot d^{-1}$)	6.39	6.48	0.9252
	Expt. 2		
Leaf area (cm^2)	303	149	0.0001
Leaf expansion ($mm \cdot d^{-1}$)	6.57	4.67	0.0003
Root extension ($mm \cdot d^{-1}$)	6.58	6.88	0.9692
	Expt. 3		
Leaf area (cm^2)	320	123	0.0001
Leaf expansion ($mm \cdot d^{-1}$)	7.35	2.71	0.0001
Root extension ($mm \cdot d^{-1}$)	7.38	7.44	0.8359

[z]n = 12 (mean of six 'Tainung 2' and six 'Sunrise' plants).

During Expt. 1, plants experienced mean daytime wind speeds of 3.11 $m \cdot s^{-1}$ and night wind speeds of 1.62 $m \cdot s^{-1}$. Stem height, area

During Expt. 2, ambient winds were 3.96 $m \cdot s^{-1}$ during the daytime and 2.15 $m \cdot s^{-1}$ during night hours. Significance of sources of

During Expt. 3, ambient winds were 4.25 $m \cdot s^{-1}$ during the day and 3.28 $m \cdot s^{-1}$ during the night. The repeated-measures ANOVA re-

Wind

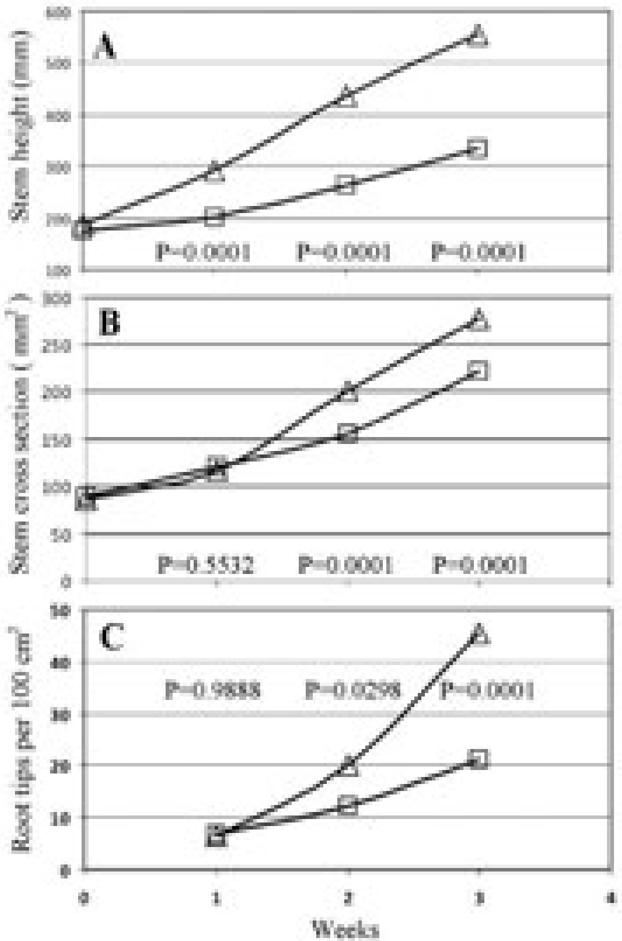


Fig. 2. Stem height (A), stem cross-section (B), and root tip density (C) of *Carica papaya* seedlings protected from (Δ) or exposed to (□) easterly ambient winds in north Guam from 4 to 25 Sept. 2009. n = 12 (mean of six 'Tainung 2' and six 'Sunrise' plants).

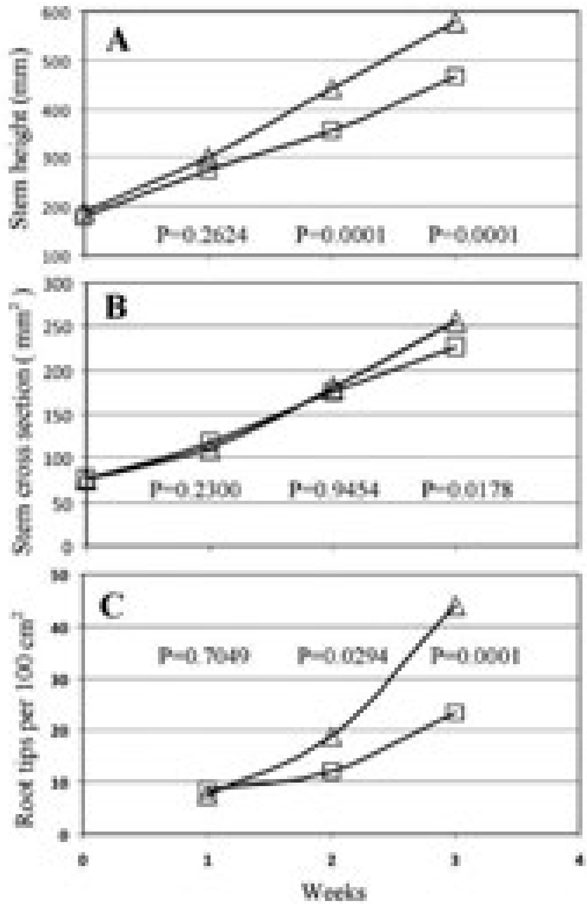


Fig. 1. Stem height (A), stem cross-section (B), and root tip density (C) of *Carica papaya* seedlings protected from (Δ) or exposed to (□) easterly ambient winds in north Guam from 3 to 24 May 2009. n = 12 (mean of six 'Tainung 2' and six 'Sunrise' plants).

Wind

Structures were constructed in a north–south direction to provide plants on the west side with one of three levels of wind exposure: 0 % (fully protected), 36 % or 100 % (fully exposed). Full protection was provided using a polypropylene sheet to exclude all ambient wind. Exposure to 36 % ambient wind was provided by covering the structure with a fabric screen. Plants receiving 100 % exposure received no protection from the ambient wind. A randomized complete block design was used, with nine structures established within three blocks.

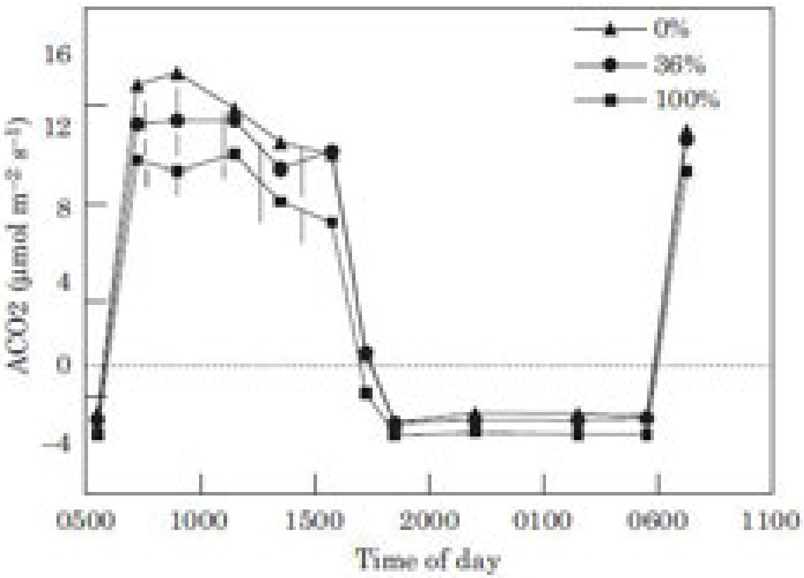


FIG. 2. Net CO_2 assimilation (A_{CO_2}) of 'Tainung 2' leaves on 14 and 15 Dec. 1995 as influenced by time of day and exposure to wind. Sunrise was at 0635 h, and sunset was at 1756 h. Vertical bars represent standard error. $n = 6$.

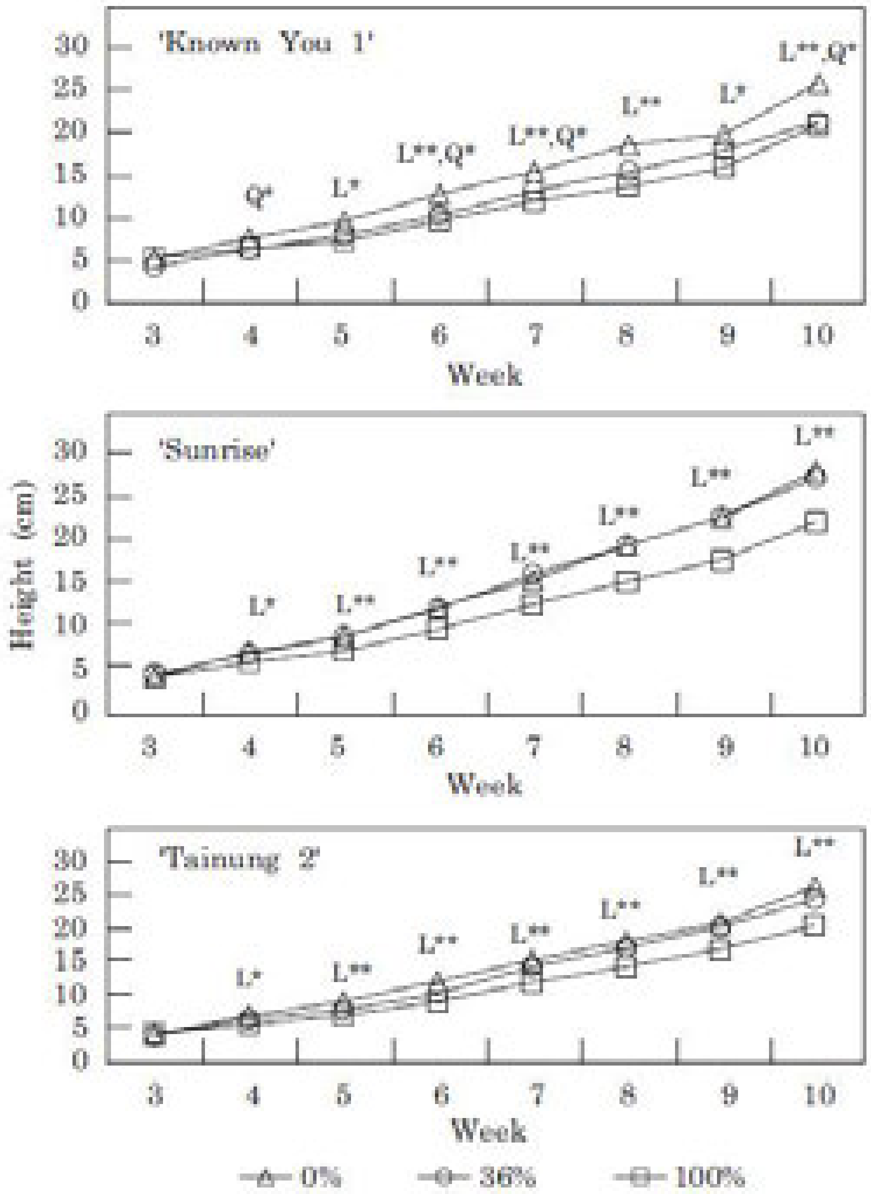


FIG. 1. Height of papaya seedlings receiving 0, 36 or 100 % wind exposure from 9 Mar. to 18 May 1996. Measurements began in week 3. *,** indicates linear (L) or quadratic (Q) regression models were significant at $P \leq 0.05$ or $P \leq 0.01$. $n = 6$.

Wind

TABLE 1. *Leaf (LDW), stem (SDW), root (RDW), and total (TDW) dry weights, and root:canopy ratio (RCR) of papaya seedlings receiving 0, 36 or 100% wind exposure from 9 Mar. 1996 to 18 May 1996*

Variable	% Wind exposure 0	36	100	Sig.	r^2
'Known You 1'					
LDW (g)	2·33	2·35	1·92	ns	
SDW (g)	1·25	1·18	0·90	L**	0·46
RDW (g)	3·12	3·30	3·78	ns	
TDW (g)	6·70	6·83	6·60	ns	
RCR	0·92	0·94	1·34	L**	0·42
'Sunrise'					
LDW (g)	1·95	2·11	1·72	ns	
SDW (g)	1·09	1·36	0·96	L* Q**	0·24, 0·69
RDW (g)	3·85	3·33	3·46	ns	
TDW (g)	6·89	6·81	6·05	ns	
RCR	1·27	0·97	1·36	Q**	0·45
'Tainung 2'					
LDW (g)	2·05	2·29	1·61	L**Q**	0·38, 0·67
SDW (g)	1·63	1·24	0·77	L*	0·22
RDW (g)	3·14	3·87	3·32	ns	
TDW (g)	6·81	7·39	5·70	ns	
RCR	0·97	1·15	1·40	ns	

ns, *, ** Indicates non-significant, or linear (L) or quadratic (Q) regression models are significant at $P \leq 0·05$ or $P \leq 0·01$, respectively. $n = 6$.

TABLE 2. *Height (Ht), leaf (LDW), stem (SDW), and root (RDW) dry weight, dry weight gain, leaf area (LA), root : canopy ratio (RCR), and daytime and night-time whole plant evapotranspiration (E_{wp}) of papaya seedlings receiving 0 36 or 100 % wind exposure from 11 Nov. to 16 Dec. 1995*

	% Wind exposure				
Variable	0	36	100	Sig.	r^2
'Known You 1'					
Ht (cm)	40·7	39·2	30·8	L*	0·33
LDW (g)	4·76	5·02	2·85	L**	0·36
SDW (g)	3·04	3·24	2·24	ns	
RDW (g)	5·80	5·50	4·39	ns	
Dry wt (g)	13·32	13·46	9·19	L*	0·25
RCR	0·78	0·69	0·91	ns	
LA (cm^2)	1186	1311	767	L*	0·30
Day E_{wp} ($mg\ m^{-2}\ s^{-1}$)	77·1	70·8	49·0	L**	0·83
Night E_{wp} ($mg\ m^{-2}\ s^{-1}$)	3·6	3·7	5·7	L**Q**	0·86, 0·95
'Sunrise'					
Ht (cm)	47·0	46·5	41·3	L**	0·49
LDW (g)	4·18	4·93	3·57	Q**	0·49
SDW (g)	3·46	4·39	2·72	Q**	0·54
RDW (g)	4·61	6·06	5·08	ns	
Dry wt (g)	12·04	15·18	11·15	Q**	0·60
RCR	0·60	0·67	0·81	L*	0·24
LA (cm^2)	1112	1186	936	L*,Q*	0·27, 0·43
Day E_{wp} ($mg\ m^{-2}\ s^{-1}$)	74·7	62·7	57·6	L**Q**	0·67, 0·79
Night E_{wp} ($mg\ m^{-2}\ s^{-1}$)	4·0	3·6	5·9	L**,Q**,	0·63, 0·84
'Tainung 2'					
Ht (cm)	46·8	45·5	40·0	L**	0·42
LDW (g)	5·13	5·62	4·75	ns	
SDW (g)	3·75	4·76	3·62	ns	
RDW (g)	6·20	6·84	6·37	ns	
Dry wt (g)	14·84	16·98	14·49	ns	
RCR	0·69	0·72	0·77	ns	
LA (cm^2)	1326	1482	1086	ns	
Day E_{wp} ($mg\ m^{-2}\ s^{-1}$)	84·9	71·7	54·6	L**	0·87
Night E_{wp} ($mg\ m^{-2}\ s^{-1}$)	3·0	3·6	5·6	L**	0·83

Figure 1. Cutting prepared for IBA treatment.

ORIGINAL ARTICLE

Effects of indol butyric acid concentration on propagation from cuttings of papaya cultivars 'Golden' and 'Uenf/Caliman 01'

Omar Schmildt[1], Eliemar Campostrini[2], Edilson Romais Schmildt[1], Alena Torres Netto[2], Anderson Lopes Peçanha[1], Tiago Massi Ferraz[2], Geraldo Antônio Ferreguetti[3], Rodrigo Sobreira Alexandre[1] and Julián Cuevas González[4,*]

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Fruits, 2016, vol. 71(1), p. 27-33

DOI: 10.1051/fruits/2015043

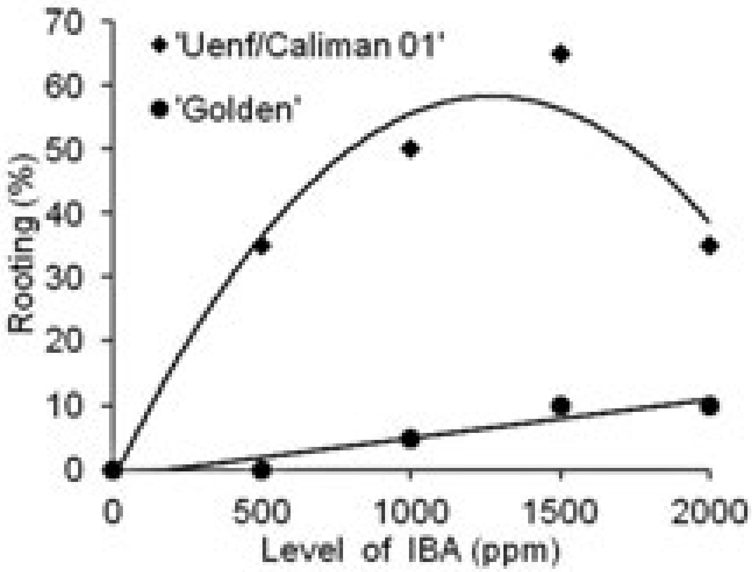

Figure 2. Rooting success in cvs 'Golden' and 'Uenf/Caliman 01', in response to different levels of IBA 70 days after treatment. $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose). Equations: 'Golden', $Y_i = -1.0 + 0.006x$, $R^2 = 0.90$; 'Uenf/Caliman 01', $Y_i = -1.57 + 0.093x - 0.000037x^2$, $R^2 = 0.95$.


28 dias

Table I. Vegetative characteristics of cv. 'Uenf/Caliman 01' papaya cuttings *versus* seedlings: plant height at transplanting (PH1) and after 4.5 months in the field (PH2), trunk diameter (Trunk), leaf number (Leaves) and canopy diameter (Canopy).

Propagation procedure	Vegetative characteristics[y]				
	PH1 (cm)	PH2 (cm)	Trunk (cm)	Leaves	Canopy (cm)
Cuttings	21.3 ± 0.9	67.2 ± 2.8	6.6 ± 0.3	21.3 ± 1.0	187.3 ± 9.9
Seeds	9.3 ± 0.3	126.8 ± 2.2	8.3 ± 0.3	25.2 ± 0.6	179.5 ± 3.8
P value[z]	< 0.0001	< 0.0001	0.0001	0.0027	0.4677

[y] Means ± standard errors ($n = 15$); [z] *t*-Student test.

Table II. Reproductive characteristics of cv. 'Uenf/Caliman 01' in papaya cuttings *versus* seedlings after 4.5 months growing in the field: flowering onset (Flowering, in days after transplanting - DAT), flowers per plant (Flowers), height for first fruit (HFruit), fruit number per plant (NbFruits), length of the portion of the stem bearing fruits (SRLength).

Propagation procedure	Reproductive characteristics[y]				
	Flowering (DAT)	Flowers	HFruit (cm)	NbFruits	SRLength (cm)
Cuttings	0.0 ± 0.0	12.3 ± 0.4	25.6 ± 2.3	9.7 ± 0.5	41.6 ± 3.1
Seeds	90.6 ± 1.2	15.4 ± 0.5	68.1 ± 1.4	12.8 ± 0.8	58.7 ± 2.6
P value[z]	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002

[y] Means ± standard errors ($n = 15$); [z] *t*-Student test.


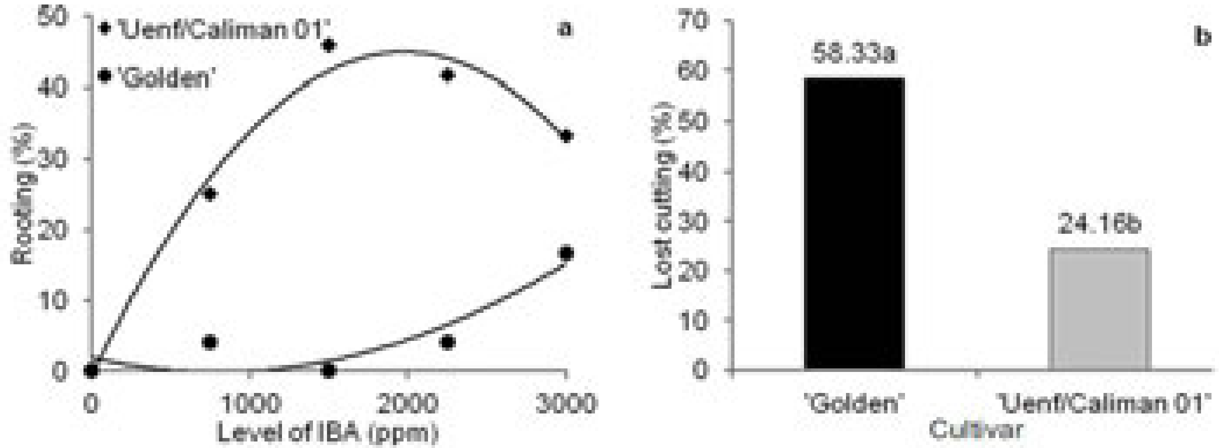

Figure 3. Rooting success 70 days after treatment in papaya cvs 'Golden' and 'Uenf/Caliman 01', in response to different concentrations of IBA. (a) Percentage of rooted cuttings. $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose). Equations: 'Golden', $Y_i = 1.9054 - 0.0051x + 0.0000032x^2$, $R^2 = 0.83$; 'Uenf/Caliman 01', $Y_i = -0.5957 + 0.046x - 0.00001164x^2$; $R^2 = 0.98$; (b) Losses due to stem rot. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$).

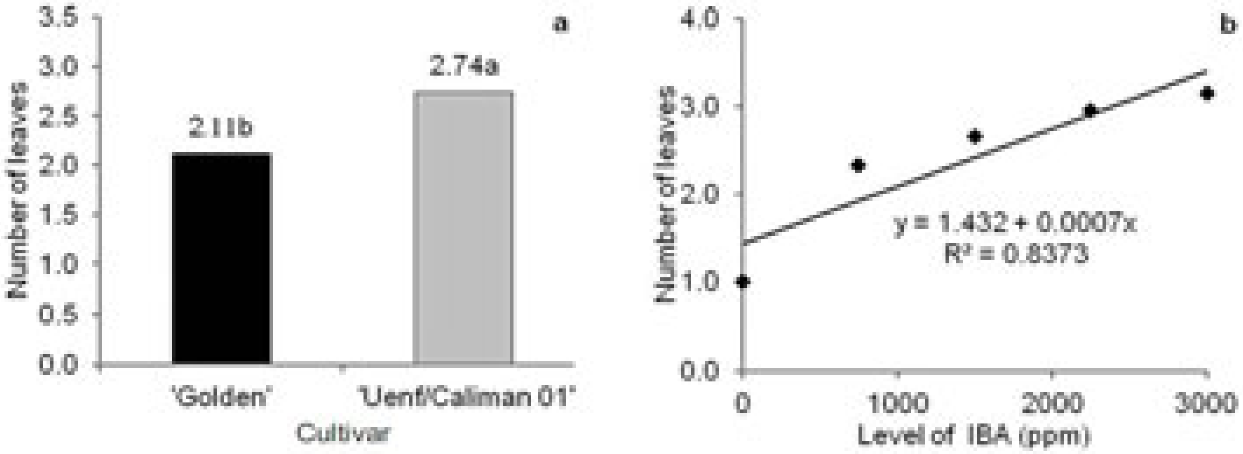

Figure 4. Leaf number in cvs 'Golden' and 'Uenf/Caliman 01' cuttings after 70 days of acclimatization: (a) Cultivar comparison; (b) Effect on leaf number of the levels of IBA applied to the base of 'Uenf/Caliman 01' cuttings. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$). $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose).

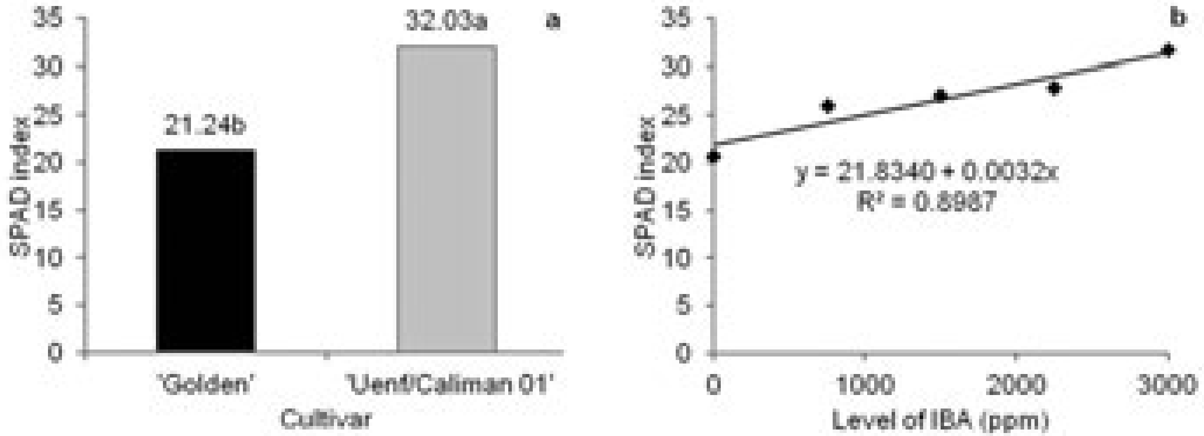

Figure 5. Chlorophyll content estimated by SPAD values in cvs 'Golden' and 'Uenf/Caliman 01' cuttings after 70 days of acclimatization: (a) Cultivar comparison; (b) Effect on SPAD values of the levels of IBA applied to the base of 'Uenf/Caliman 01' cuttings. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$). $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose).

Table III. Linear correlation of the cutting height, cutting diameter, leaf number and root volume with photosynthesis rate (A) and efficiency of photosystem II (FV/Fmax ratio) in papaya cvs 'Golden' and 'Uenf/Caliman 01'.

Variables	A (μmol CO_2 m^{-2} s^{-1})		Fv/Fmax ratio	
	Golden (n = 9)	Uenf/Caliman 01 (n = 37)	Golden (n = 9)	Uenf/Caliman 01 (n = 37)
Cutting height	0.3413^{ns}	-0.0280^{ns}		
Cutting diameter	0.7499^{**}	0.2053^{ns}		
Leaf number	0.8409^{**}	0.4266^{**}	0.0962^{ns}	-0.2745^{ns}
Root volume	0.2666^{ns}	0.2912^{ns}	0.0270^{ns}	-0.0962^{ns}

ns = not significant at 5% by t-test; ** significant at 1% by t-test.

Conclusões

Em estacas de mamoeiro ‘Golden’, em novos estudos, e para a indução de enraizamento, indica-se aumentar a concentração de AIB acima de 3000 mg L^{-1};

Estacas de mamoeiro ‘Uenf/Caliman 01’ enraízaram 65% quando tratadas com AIB a 1500 mg L^{-1}; Poucas raízes nas estacas do mamoeiro são suficientes para manter um bom estado hídrico, uma boa taxa fotossintética, uma significativa quantidade de clorofilas nas folhas e com boa eficiência na utilização de energia luminosa;

Plantas de mamoeiro propagadas por estaquia, quando cultivadas no campo apresentaram iniciação precoce de flores, menor altura de inserção dos primeiros frutos e baixa estatura, o que antecipa e facilita a colheita.

Gas-Exchange and Photochemical Efficiency in Seedling and Grafted Papaya Tree Grown under Field Condition

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[2]Faculty of Agriculture, University of Brasília, CP 04508, 70910-970 Brasília-DF, Brazil
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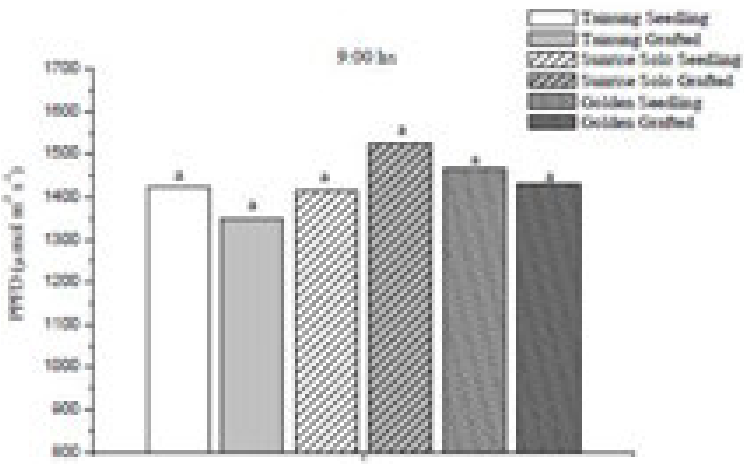
Eds.: N. Kumar et al.
Acta Hort. 851, ISHS 2010

Table 1. Grafting treatments.

Scion/stock combination	Treatment code
Tainung seedlings	TS
Tainung 01/Tainung 01	TT
Sunrise Solo seedlings	SSS
Sunrise Solo/Tainung 01	SST
Golden seedlings	GS
Golden/Tainung 01	GT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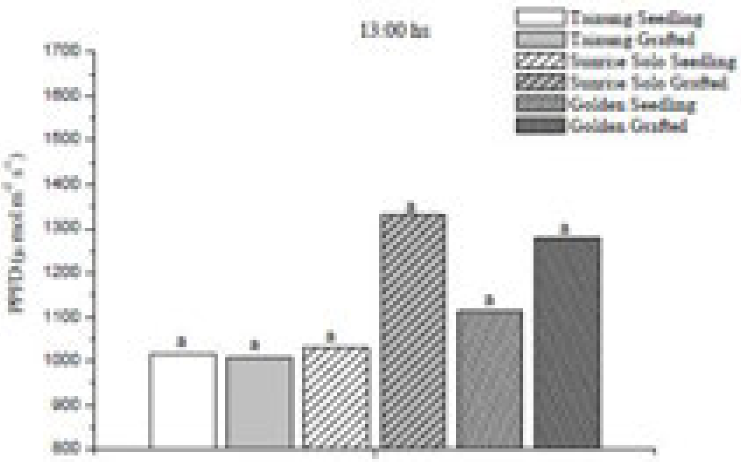
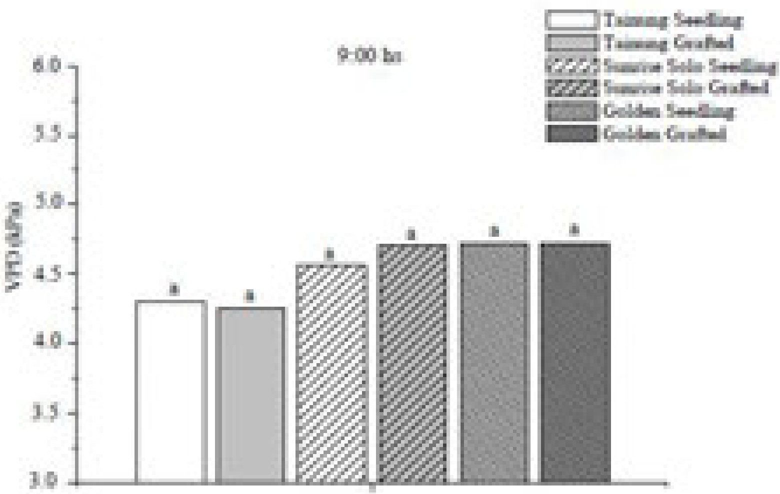
Tainung Grafted
Sunrise Solo Seedling
Sunrise Solo Grafted
Golden Seedling
Golden Grafted
PPFD (μ mol m-2 s-1)
1700
1600
1500
1400
1300
1200
1100
1000
900
800


13:00 hs
Tainung Seedling
Tainung Grafted
Sunrise Solo Seedling
Sunrise Solo Grafted
Golden Seedling
Golden Grafted
PPFD (μ mol m-2 s-1)
1700
1600
1500
1400
1300
1200
1100
1000
900
800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Tainung Grafted
Sunrise Solo Seedling
Sunrise Solo Grafted
Golden Seedling
Golden Grafted
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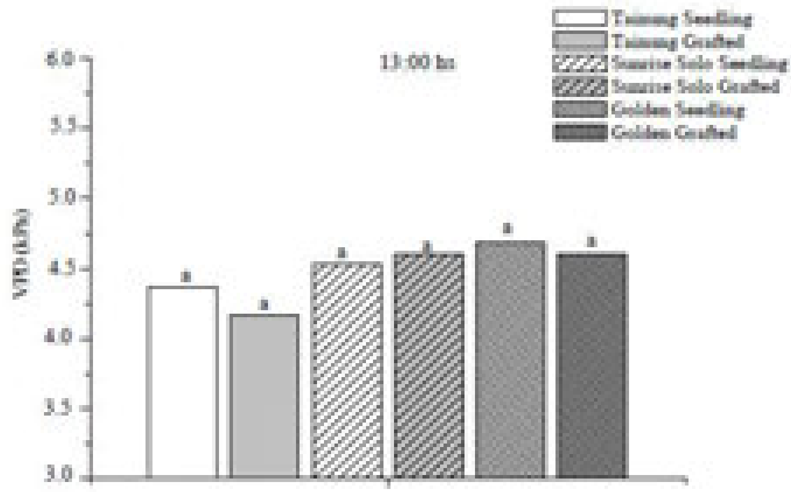
4.0
3.5
3.0


13:00 hs
Tainung Seedling
Tainung Grafted
Sunrise Solo Seedling
Sunrise Solo Grafted
Golden Seedling
Golden Grafted
VPD (kPa)
6.0
5.5
5.0
4.5
4.0
3.5
3.0

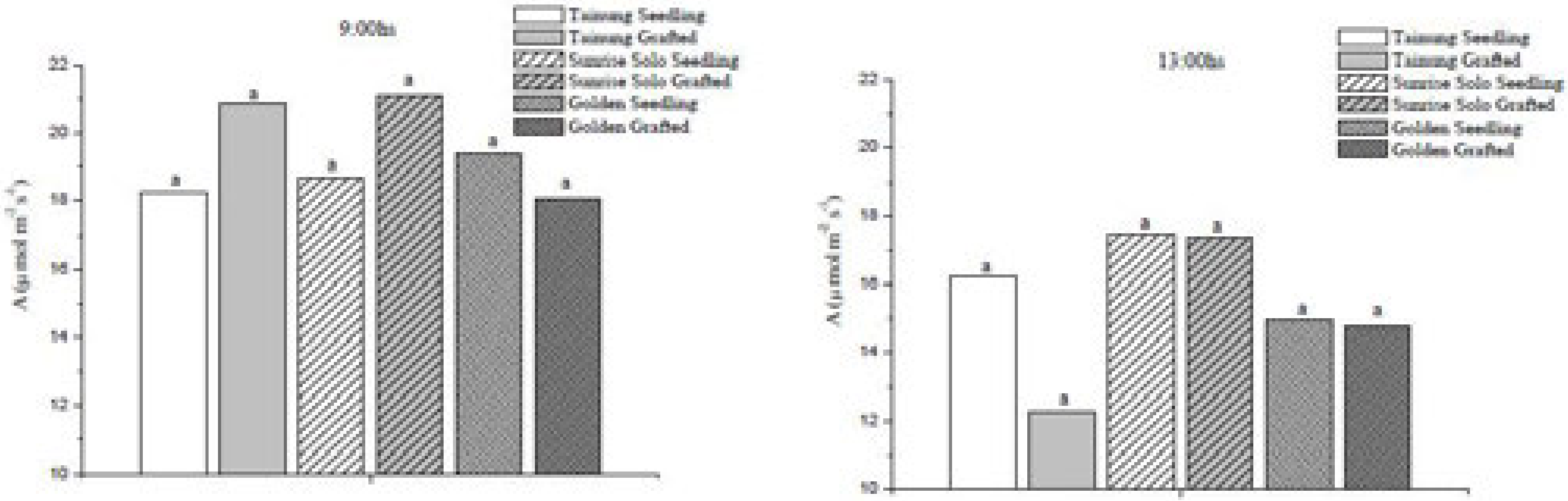
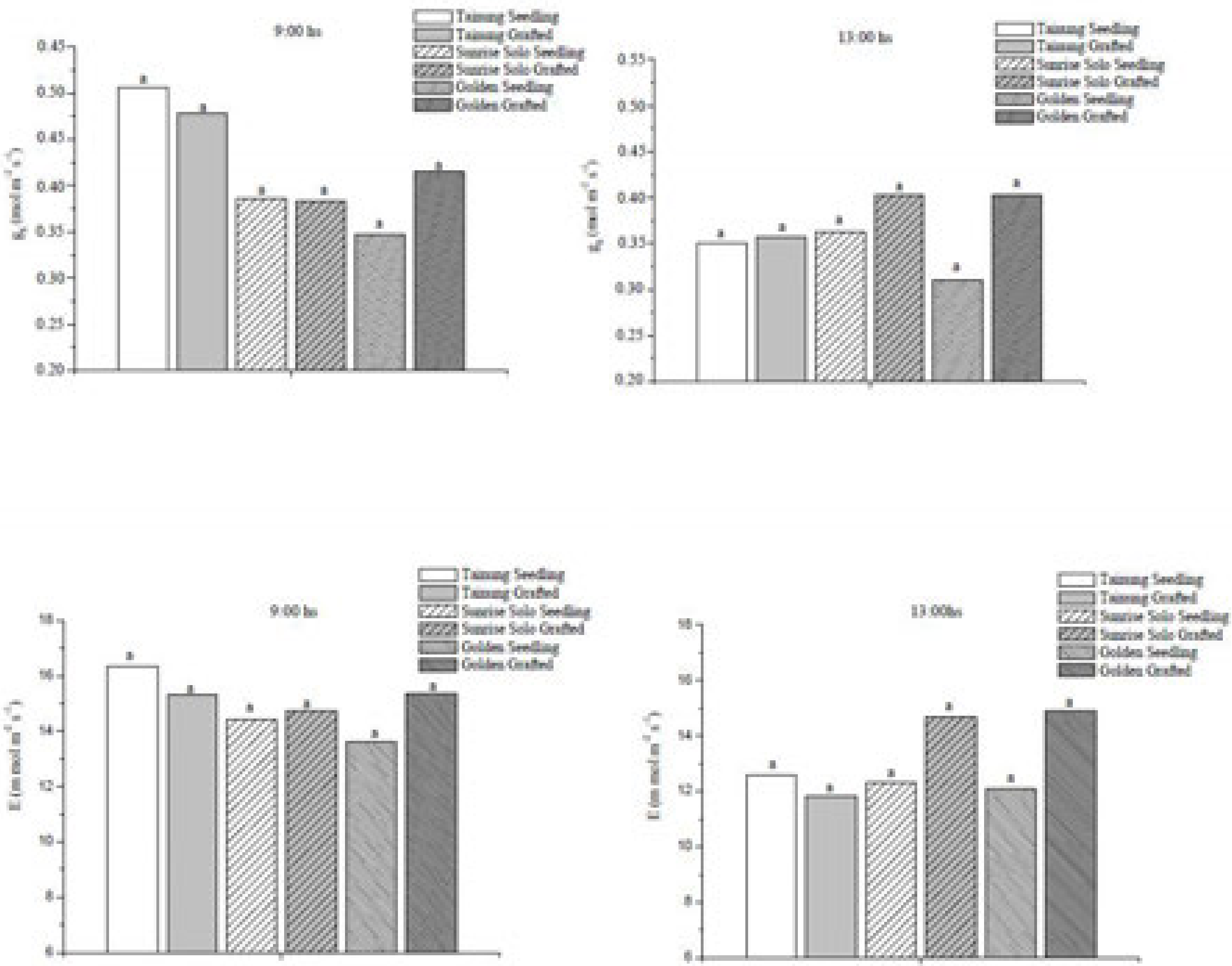
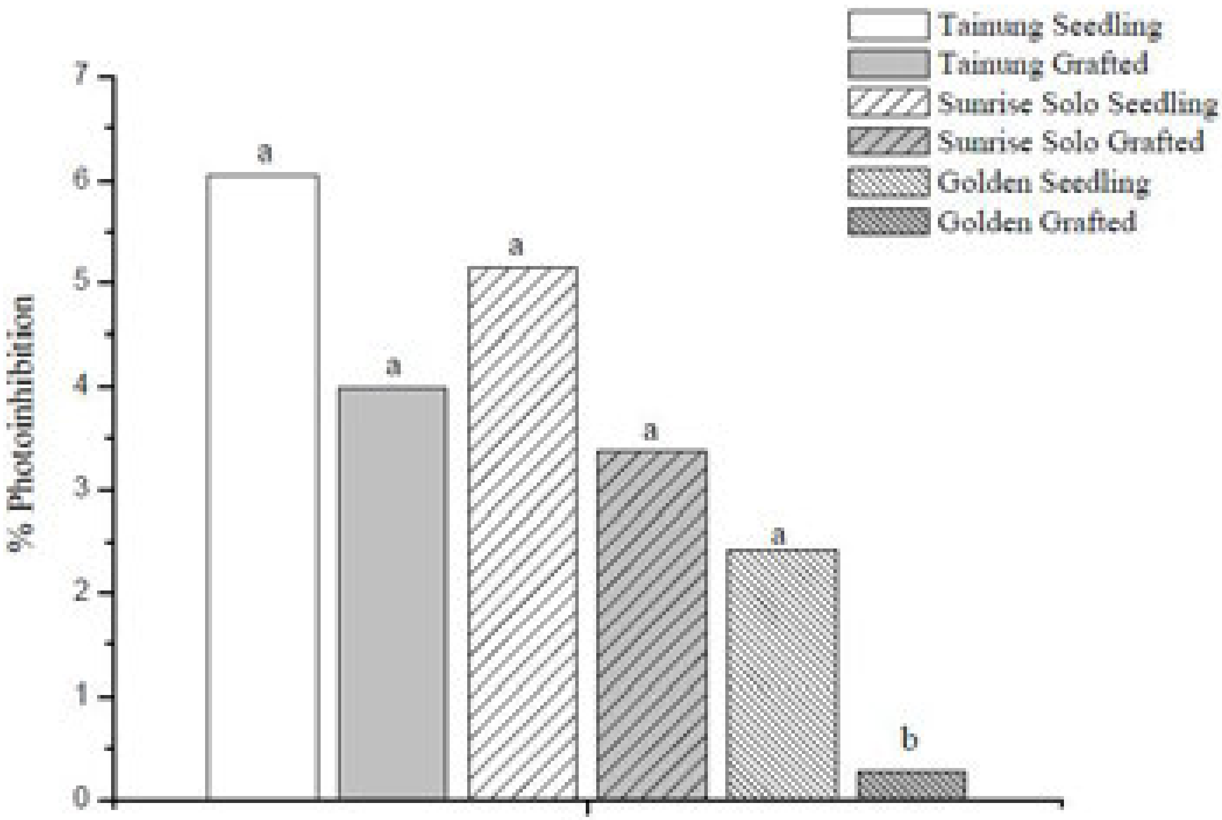


Fig. 1. Photosynthetic photon flux density (PPFD), leaf-to-air vapor pressure deficit ($VPD_{leaf\text{-}air}$), net photosynthetic rate (A) in papaya (*Carica papaya* L) cv. Golden, cv. Sunrise Solo and hybrid Tainung 01 grafted on open pollinated Tainung 01 (F2) seedlings and their respective seedlings (n=4). Means followed by the same letter are not significantly different, Tukey's test 5%.



9:00 hs
13:00 hs
Tainung Seedling
Tainung Grafted
Sunrise Solo Seedling
Sunrise Solo Grafted
Golden Seedling
Golden Grafted
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
6
8
10
12
14
16
18
a



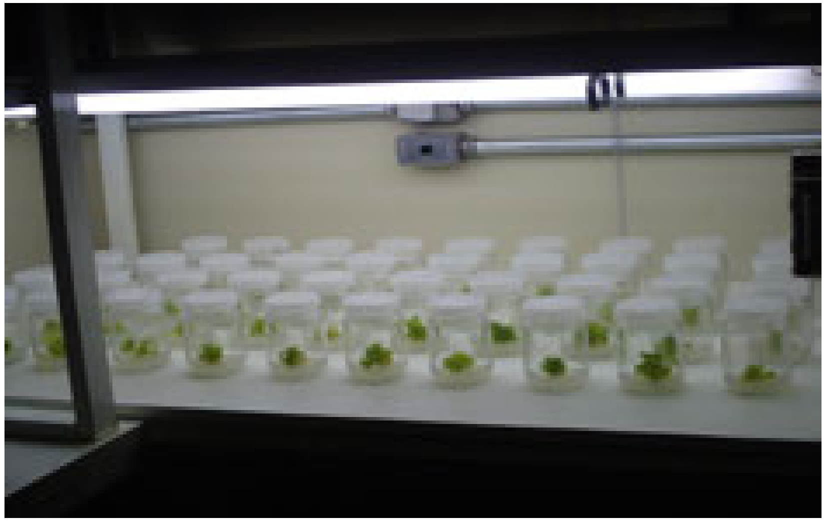
$$\% \text{ photoinhibition} = [1 - (F_v / F_{m\ 13:00}) / F_v / F_{m\ 9:00})] \times 100$$

CONCLUSIONS

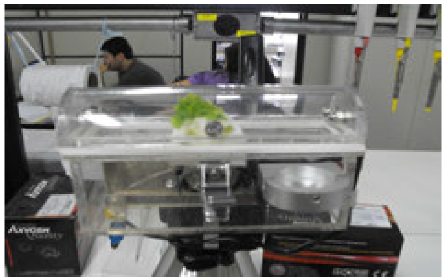
Transpiration and stomatal conductance were not affected by rootstock which means that grafting does not jeopardize the water intake in all papaya trees and the new xylem connection seems to maintain stable the root-trunk-atmosphere system. The results suggest that the performance of the grafted plants during the period was due to the capacity of the root system of Tainung 01 to provide water to the shoot and a good vascular connection between the scion and rootstock thereby maintaining high gas exchange and photochemical efficiency in the leaves and consequently a greater carbon gain.

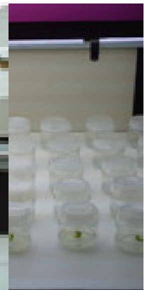
Theor. Exp. Plant Physiol.
DOI 10.1007/s40626-014-0026-y

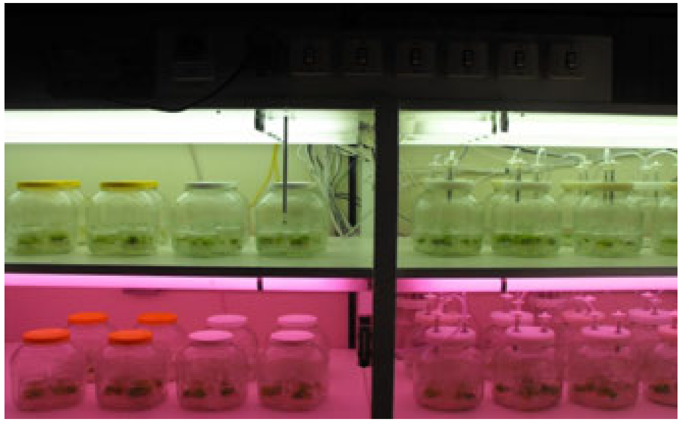
Photosynthetic capacity, growth and water relations in 'Golden' papaya cultivated in vitro with modifications in light quality, sucrose concentration and ventilation

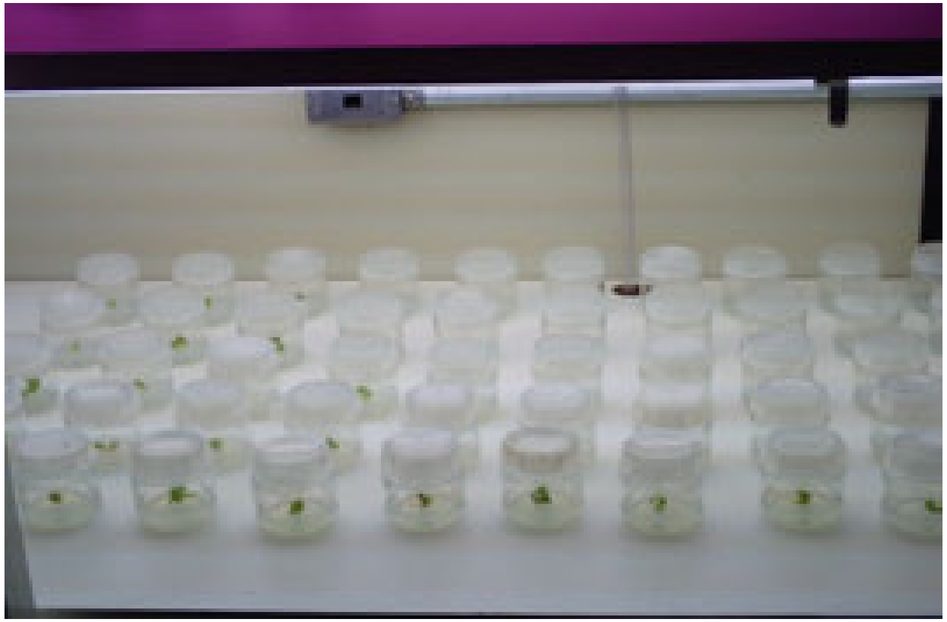


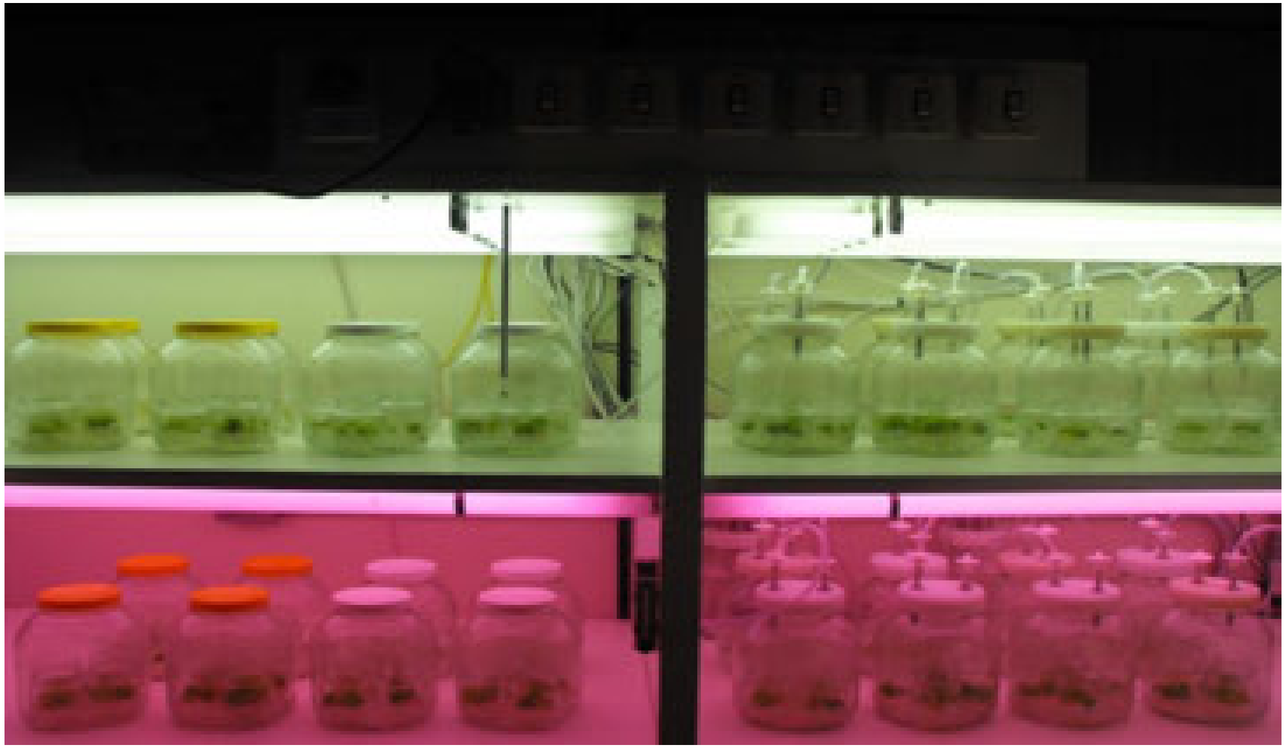
Omar Schmildt · Alena Torres Netto · Edilson Romais Schmildt · Virginia Silva Carvalho · Wagner Campos Otoni · Eliemar Campostrini

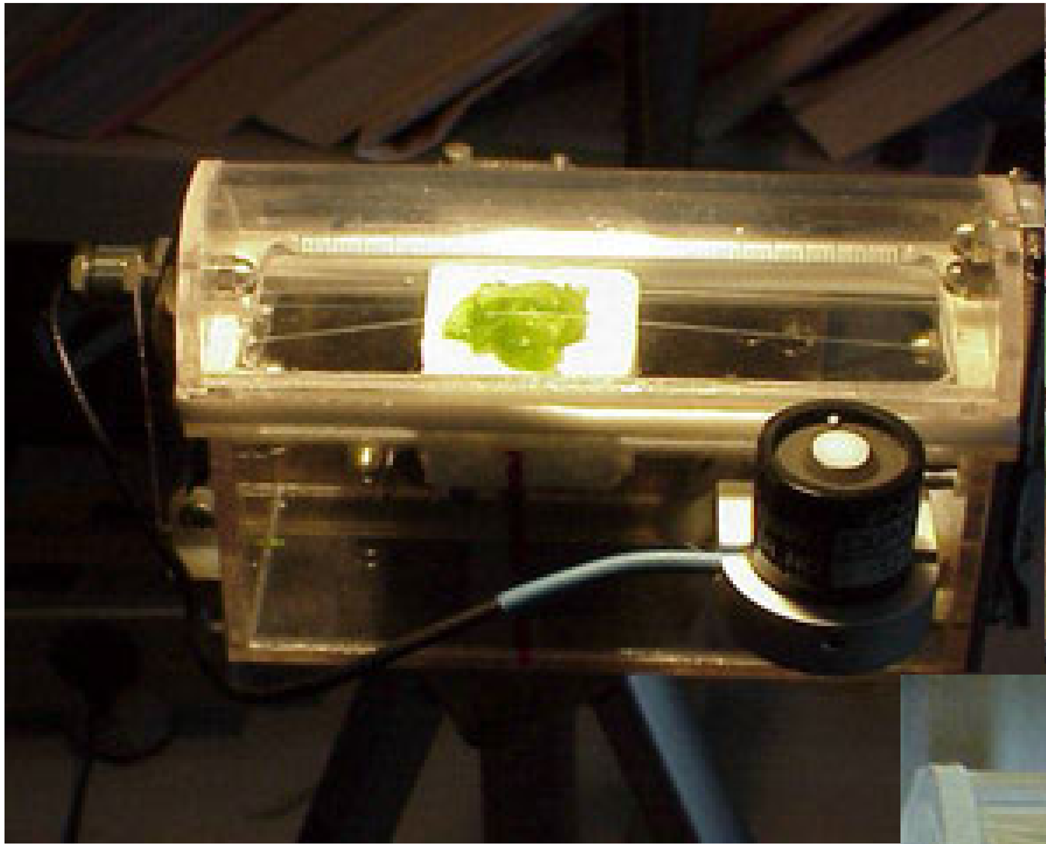


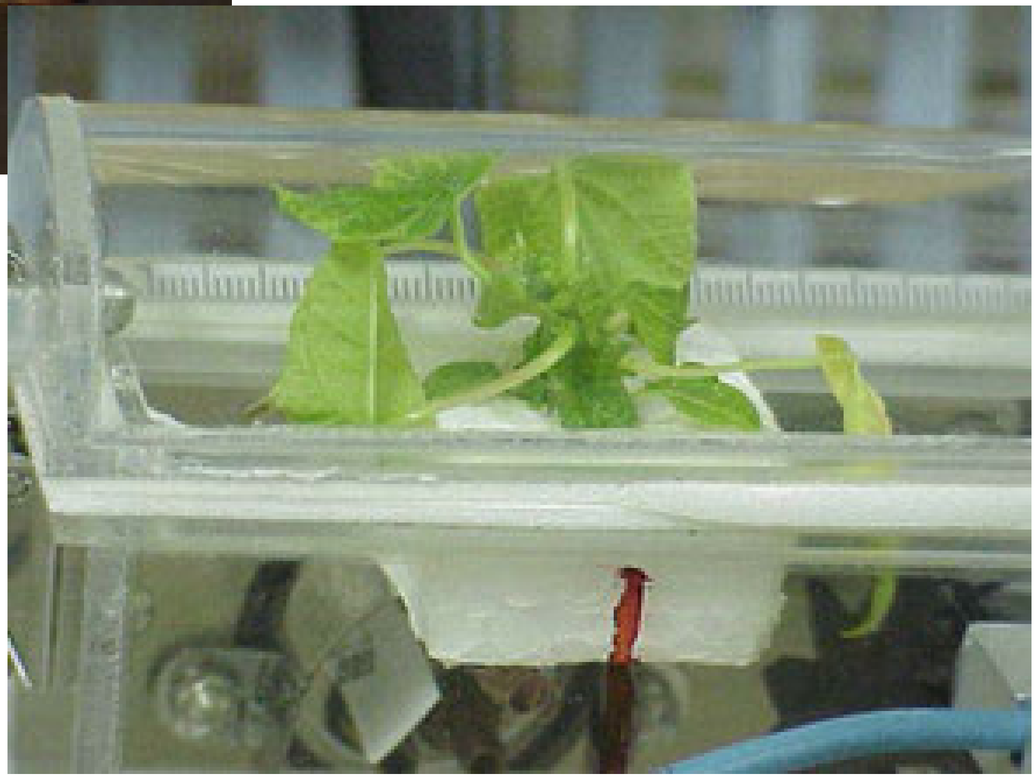


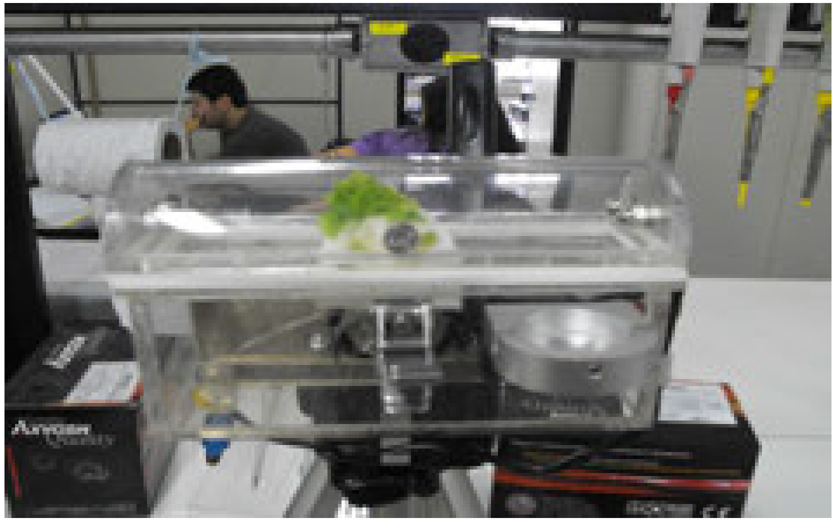


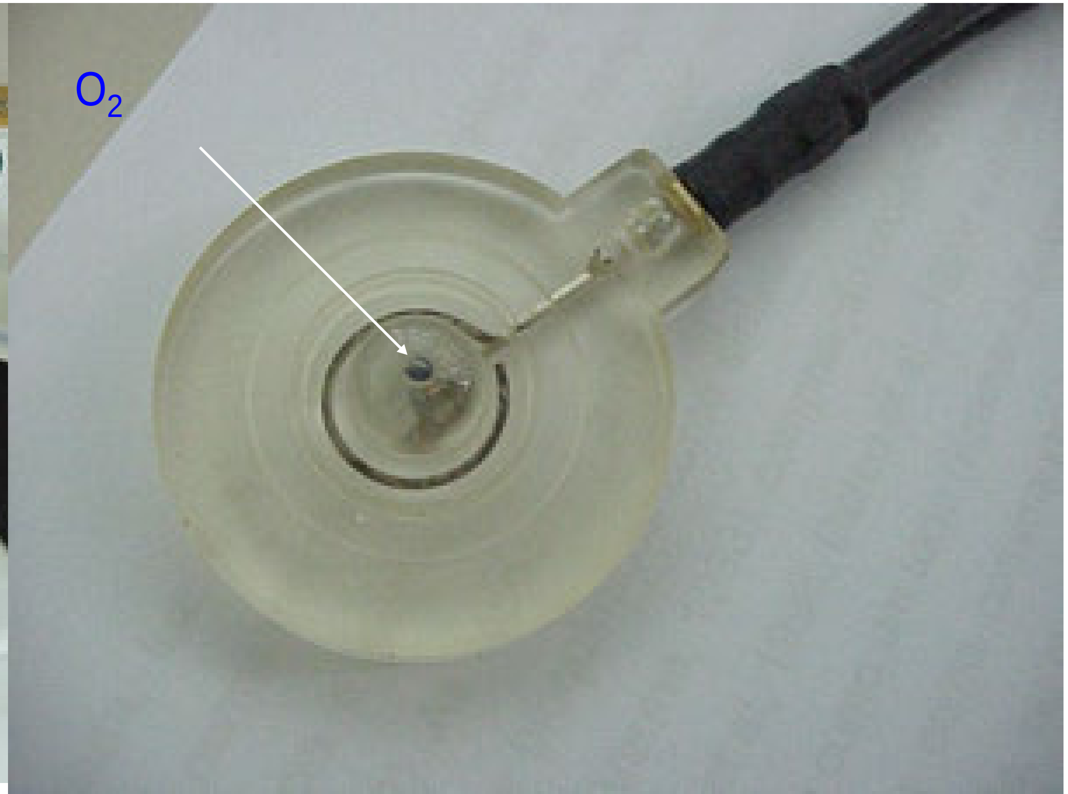











O_2

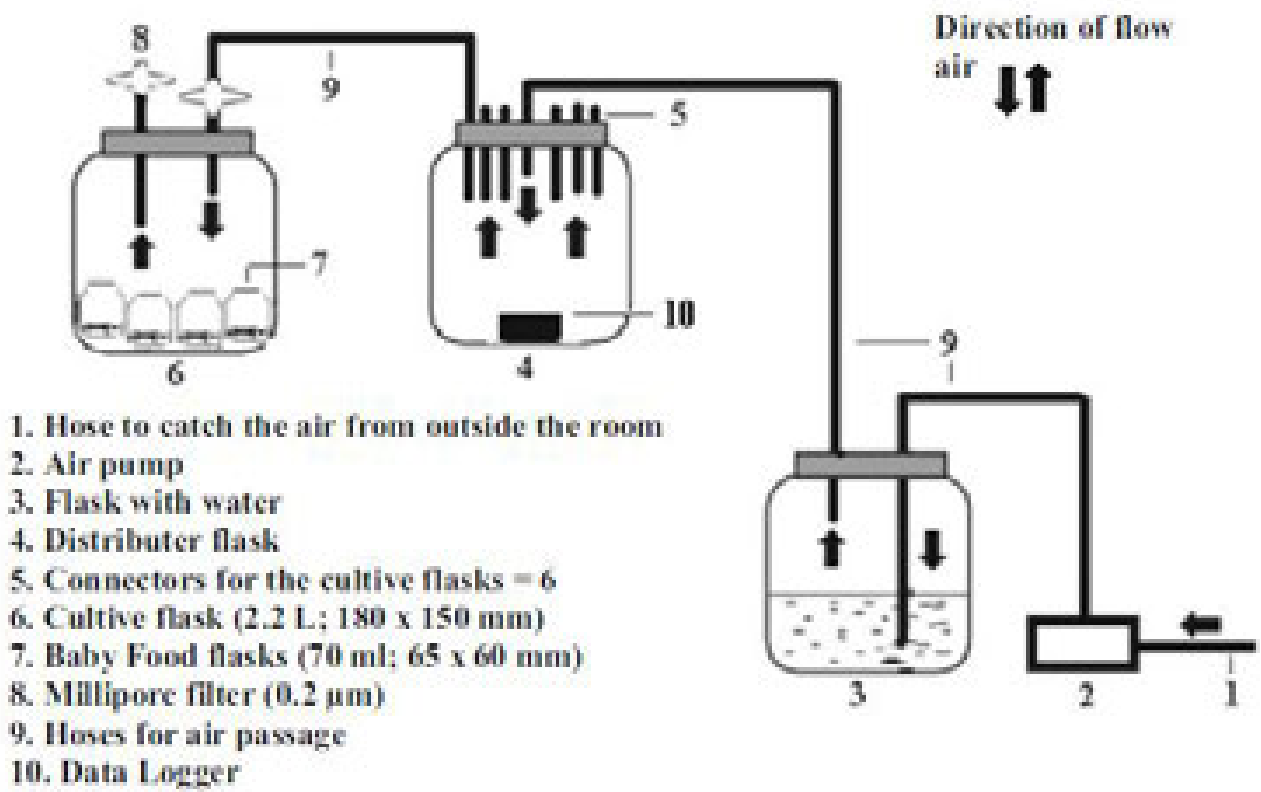


Fig. 2 A forced-air circulation system (ventilated system) used for culturing seedlings in vitro

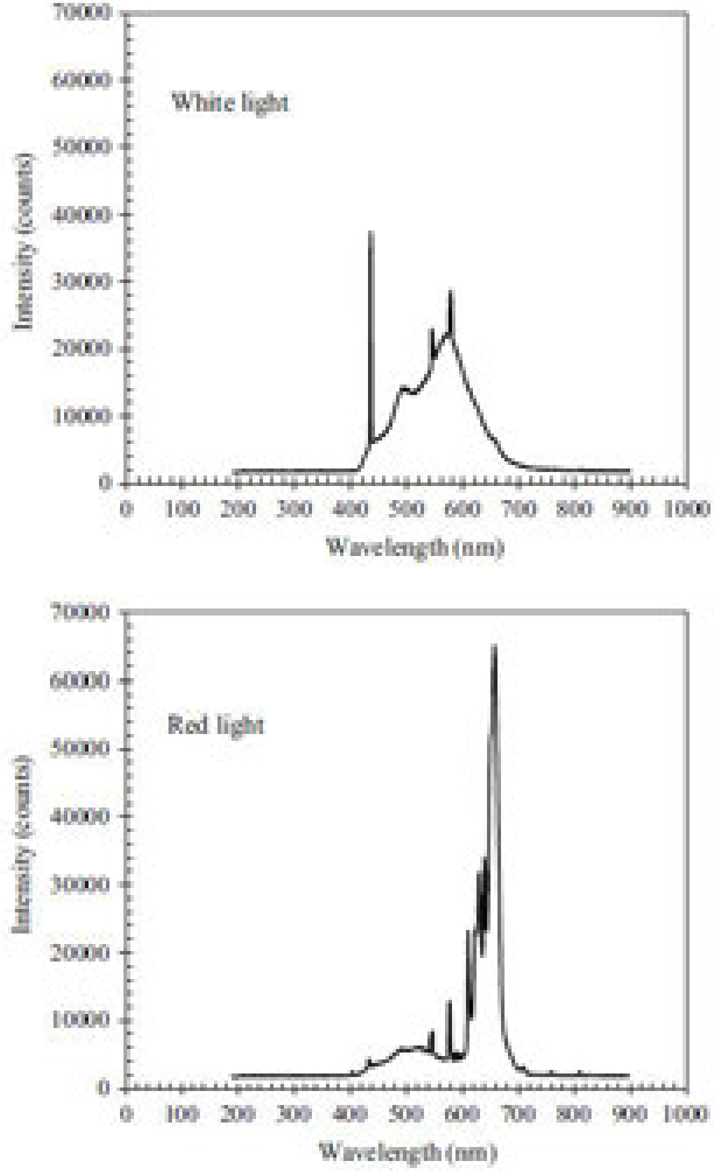


Fig. 1 Spectral energy distribution of *white* and *red lights* provided by fluorescent *white* lamps and *red* Grolux lamps respectively. Both provided a photosynthetic photon flux density of 90 μmol m^{-2} s^{-1}

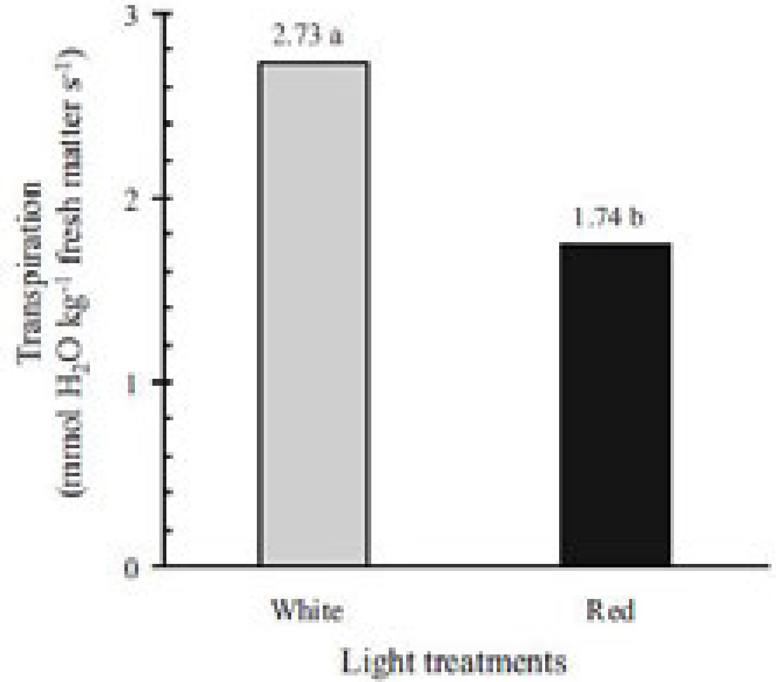


Fig. 3 Transpiration (E) in 'Golden' papaya plantlets cultured in vitro in MS multiplication culture medium under *white* or *red light*

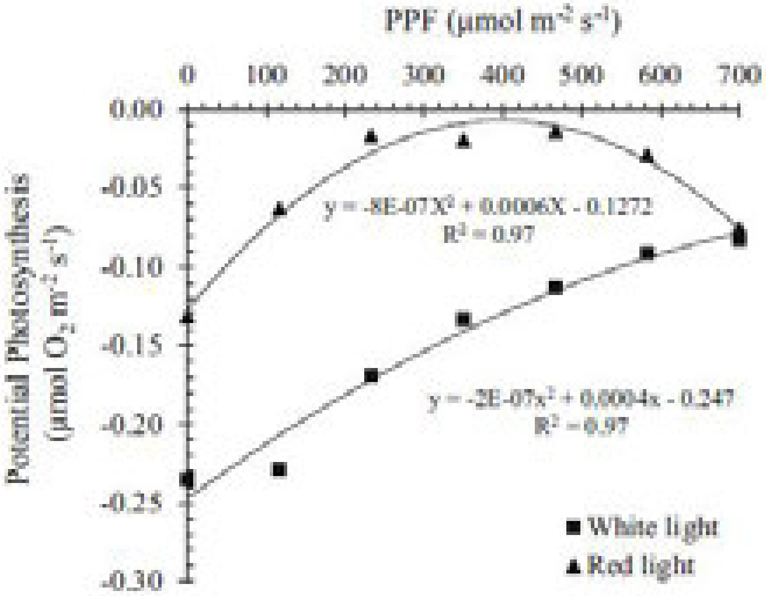


Fig. 4 The potential photosynthetic rate (μmol O_2 m^{-2} s^{-1}) in relation to the photosynthetic photon flux in 'Golden' papaya plantlets cultured in vitro in MS multiplication culture medium under *white* or *red light*

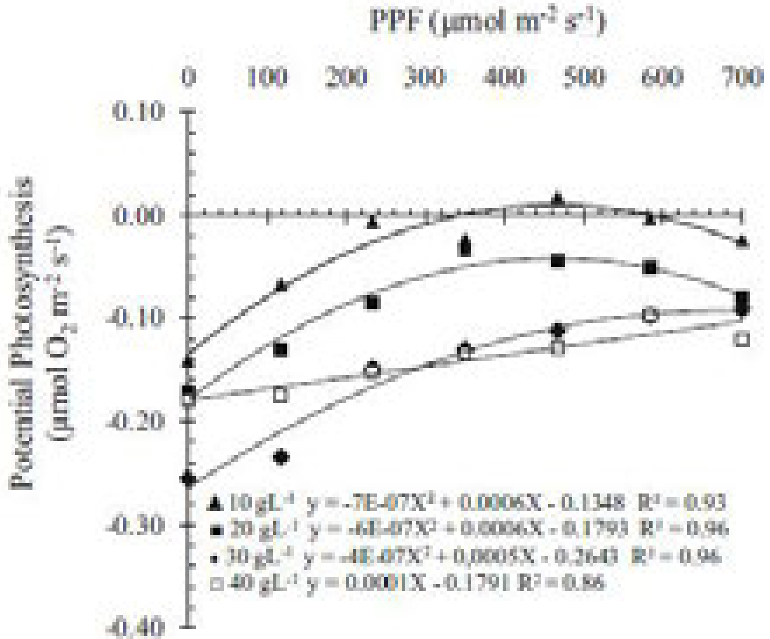


Fig. 6 The potential photosynthetic rate (μmol O_2 m^{-2} s^{-1}) in 'Golden' papaya plantlets leaves cultured in vitro in MS multiplication culture medium containing different light intensities and sucrose concentrations

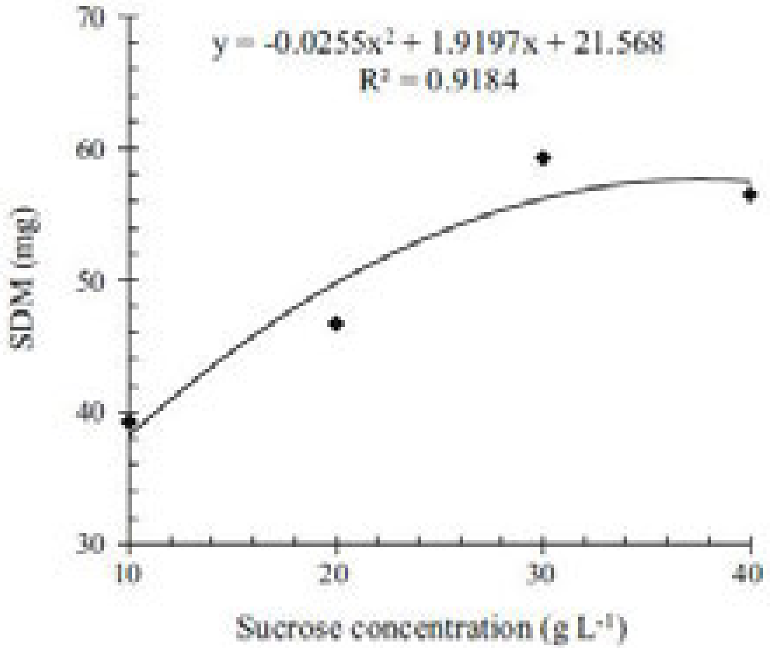


Fig. 5 Shoot dry matter (SDM) of 'Golden' papaya plantlets cultured in vitro in MS multiplication culture medium containing different sucrose concentrations

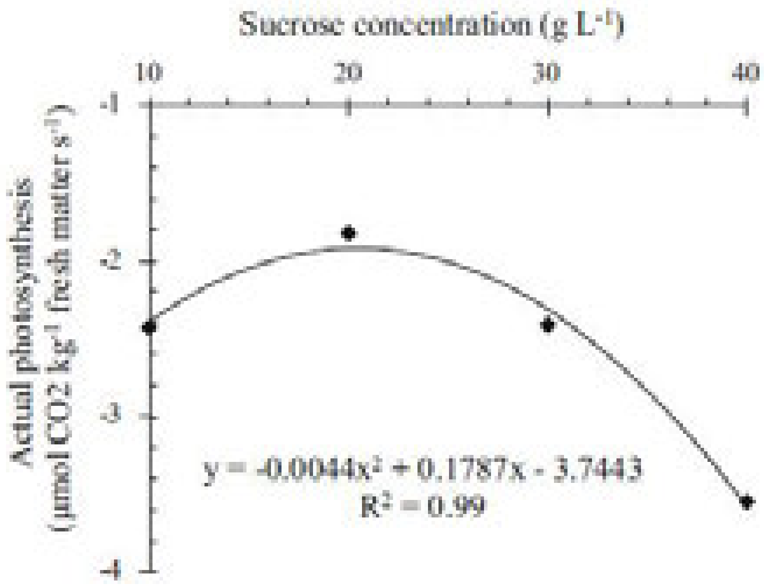


Fig. 7 The actual photosynthetic rate (A) (µmol of CO_2 kg^{-1} of fresh matter s^{-1}) of 'Golden' papaya plantlets leaves cultured in vitro in MS multiplication culture medium containing different sucrose concentrations

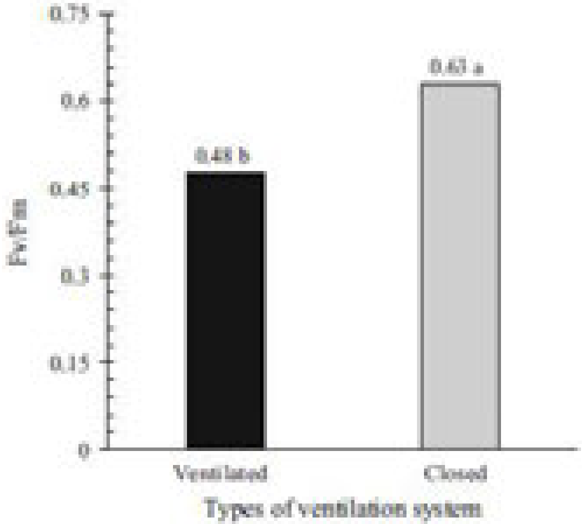


Fig. 8 The quantum efficiency in open photosystem II centres (F_v/F_m) in 'Golden' papaya plantlets cultured in vitro in MS multiplication culture medium in ventilated or closed systems

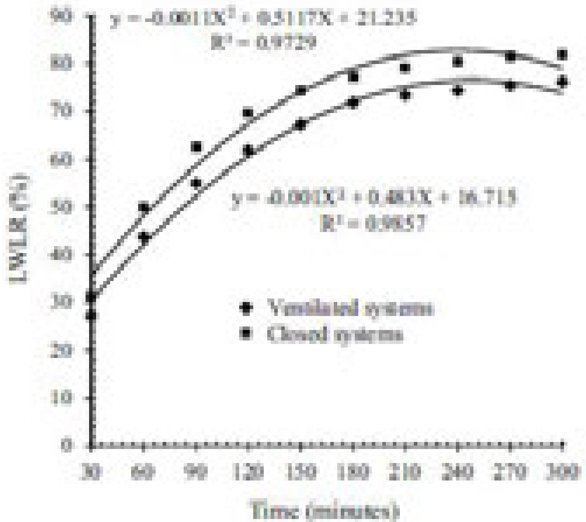
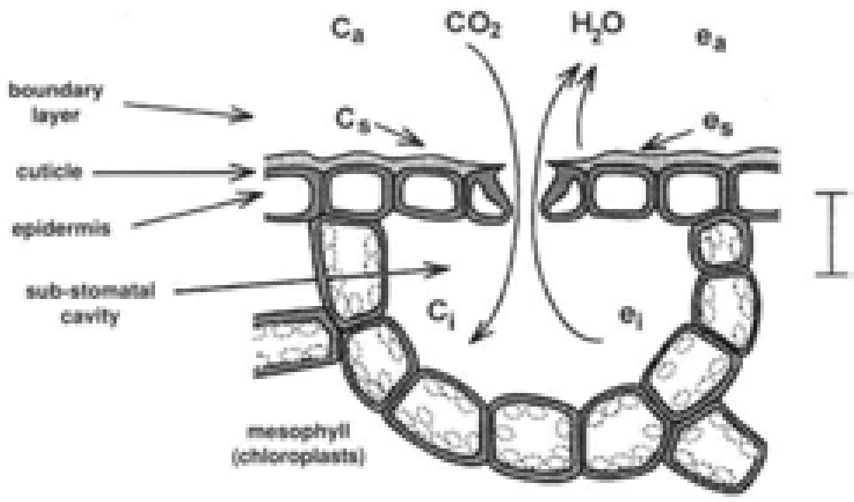


Fig. 9 The leaf water loss rate (LWLR) in 'Golden' papaya plantlets cultured in vitro in MS multiplication culture medium in ventilated or closed systems

In the present study, the increase in papaya dry matter production was due to the exogenous carbon provided by sucrose in the culture medium. No photosynthetic carbon assimilation or oxygen evolution by PS II was observed. This photochemical damage was attributable to the reduced maximum PS II quantum yield and the efficiency of the oxygen-evolving complex (OEC). We hypothesized that the reduced assimilation of carbon may have occurred due to the decreased activity in the Calvin-Benson cycle. Such damage to photosynthetic capacity was related to the presence of sucrose in the culture medium. The attempt to induce photoautotrophic metabolism in the papaya seedlings by the use of ventilated culture flasks, reduced sucrose (10 g L^{-1}) and a PPF of 90 μmol m^{-2} s^{-1} was not successful. In this species, alternative strategies to achieve a photoautotrophic metabolism and the expected biomass gain include the use of a greater photosynthetic photon flux density and an increased CO_2 concentration in the ventilated flasks in association with a markedly lower concentration (<10 g L^{-1}), or even the absence of sucrose in the culture medium.

Soil and air water

1) Air water:



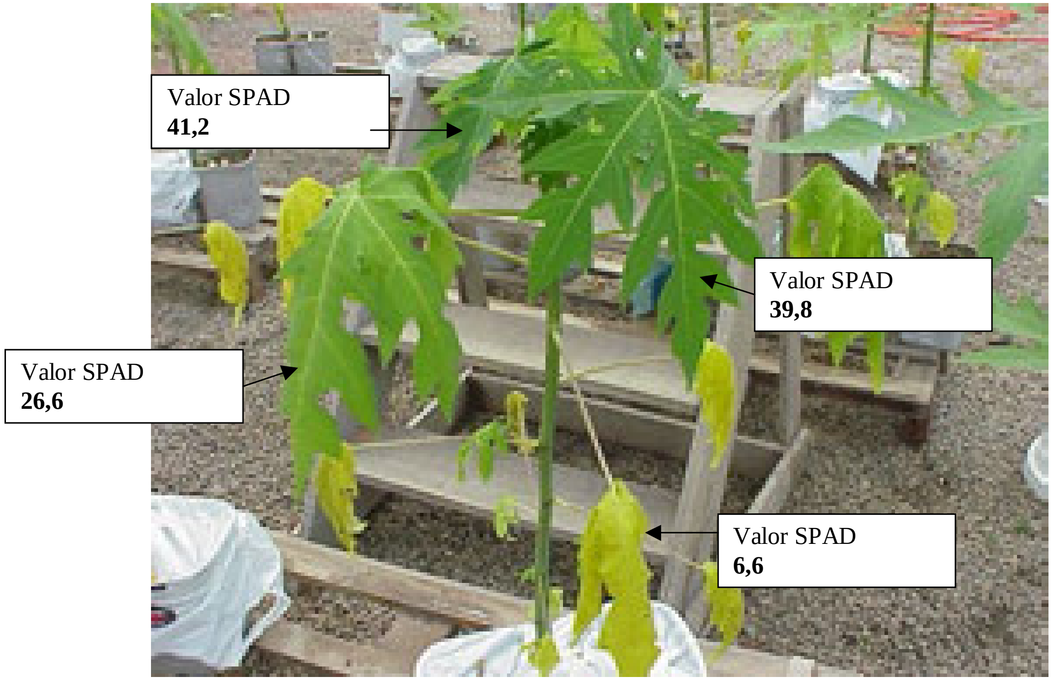
Threshold VPD values to papaya:

VPD_{air} = $< 1kPa\ (e_{sair} - e_{air})$

$VPD_{leaf\text{-}air}$ = $< 2kPa\ (e_{sleaf} - e_{air})$

2) Soil water:

Papaya exhibits both stomatal and non stomatal response to soil water deficits and the source of the response signals are both hydraulic and non-hydraulic in nature



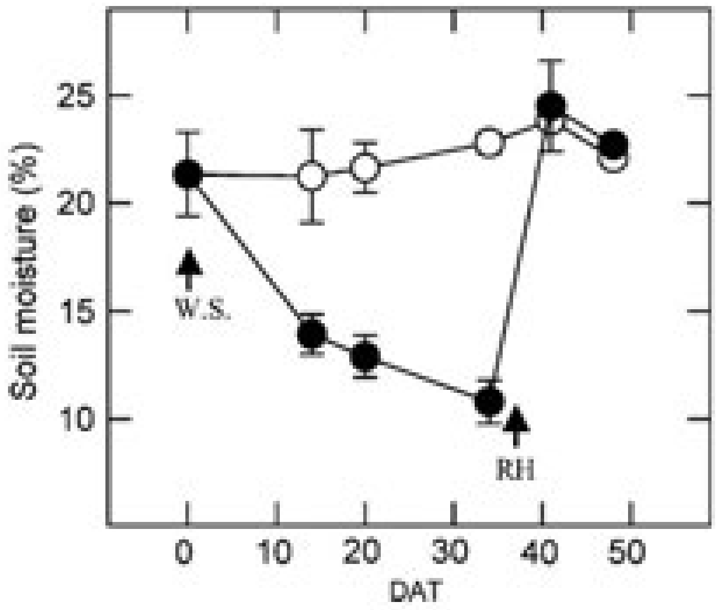


Figure 2. Moisture (%) in watered (○) and non-watered pot soils (●) of papaya seedlings. In non-watered soils, irrigation was suspended during 34 days and re-established thereafter until the end of experiment. Data are means ±SE and each value was determined by three TDR probes with three replicates per treatment ($n \geq 9$) (one probe per pot). DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

Plant and Soil (2006) 281:137–146

Responses of papaya seedlings (*Carica papaya* L.) to water stress and re-hydration: growth, photosynthesis and mineral nutrient imbalance

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[1]*Departamento de Suelos y Riegos, Instituto Canario de Investigaciones Agrarias, Apdo 60, E-38200 La Laguna, Santa Cruz de Tenerife, Spain.* [2]*Centro de Genómica, Instituto Valenciano de Investigaciones Agrarias, E-46113 Moncada, Valencia, Spain.* [3]*Corresponding author**

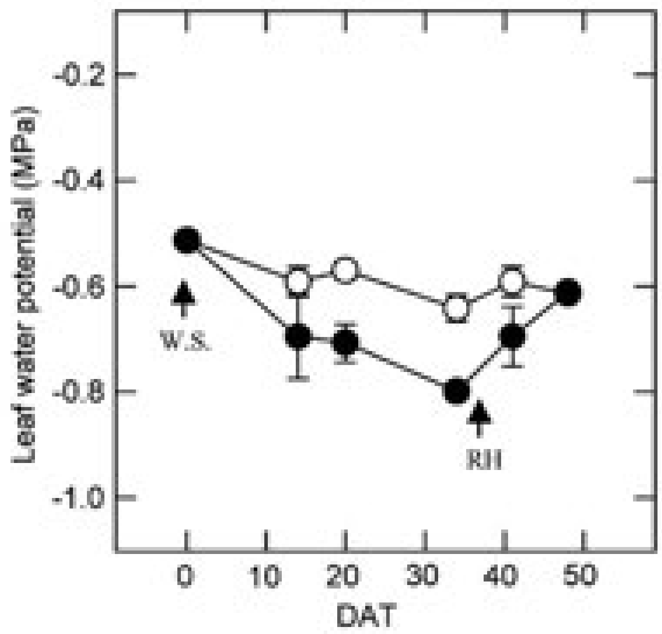


Figure 1. Leaf water potential in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Data are means ±SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

Baixinho de Santa Amália genotype
70L pots
Greenhouse
Maximum PAR 1200µmol m^{-2} s^{-1}
Severe water stress: ψ_{leaf} =-0,8MPa
Regular irrigated plants: ψ_{leaf} =-0,6MPa

Table 1. Plant height and stem circumference of papaya seedlings subjected to water stress and re-hydration. The treatment consisted of irrigation suppress during 34 days and re-watering establishment thereafter until 48 days (total experimental period). The data ($n \geq 9$) presented in each line followed by dissimilar letters differ significantly at ($P \leq 0.05$). *: $P \leq 0.01$. **: $P \leq 0.001$

Treatments	Plant height (cm)		Stem circumference (cm)	
	Control	Water stress	Control	Water stress
Water stress (Days)				
0	38.45 ± 0.67a	38.50 ± 0.56a	8.23 ± 0.09a	8.08 ± 0.15a
14	41.67 ± 0.80a	39.63 ± 0.58a	9.04 ± 0.10a	8.72 ± 0.13a
20	42.21 ± 1.06a	39.88 ± 0.60b	9.51 ± 0.11a	8.94 ± 0.15b*
34	43.83 ± 1.15a	40.13 ± 0.67b	9.79 ± 0.12a	8.98 ± 0.12b**
Rehydration (Days)				
41	46.13 ± 1.28a	41.20 ± 0.87b	10.10 ± 0.23a	8.98 ± 0.19b*
48	46.83 ± 1.86a	43.25 ± 1.75b	10.60 ± 0.32a	9.40 ± 0.35b

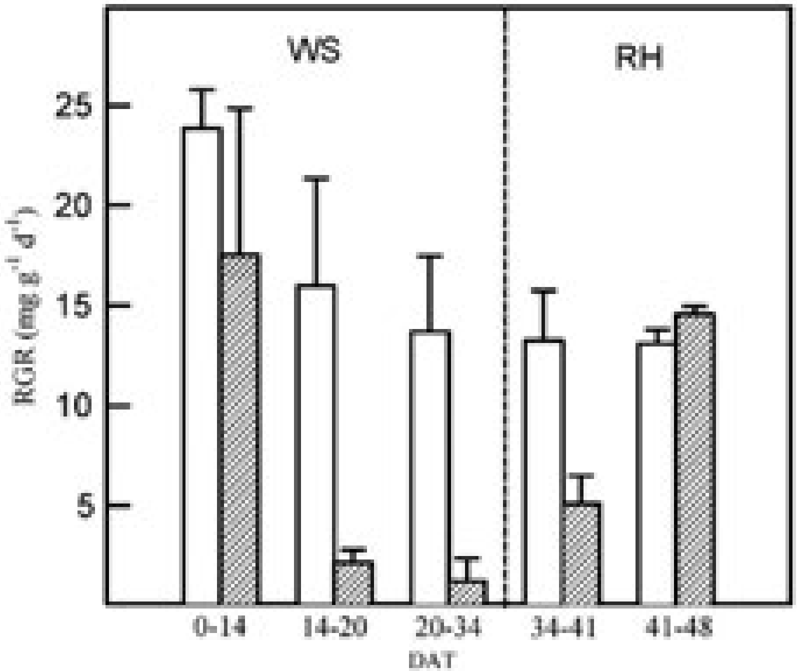


Figure 3. Relative growth rate using stem DW of papaya seedlings. Treatments were: regular irrigated plants (☐) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (▩). Data are means ± SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

Table 2. Root fresh weight of papaya seedlings subjected to water stress and re-hydration. The treatment consisted of irrigation suppress during 34 days and re-watering establishment thereafter until 48 days (total experimental period). The data ($n \geq 9$) presented in each line followed by dissimilar letters differ significantly at ($P \leq 0.05$)

Treatments	Root fresh weight (g)	
	Control	Water stress
Water stress (Days)		
34	181.9 ± 16.5a	101.4 ± 18.7b
Rehydration (Days)		
48	183.0 ± 23.5a	119.7 ± 8.70b

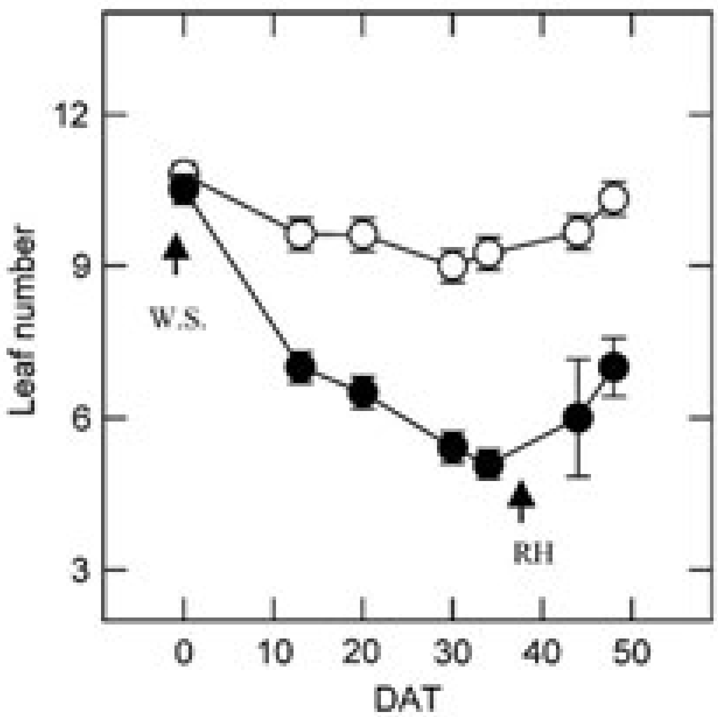


Figure 4. Number of remaining leaves in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Data are means ± SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

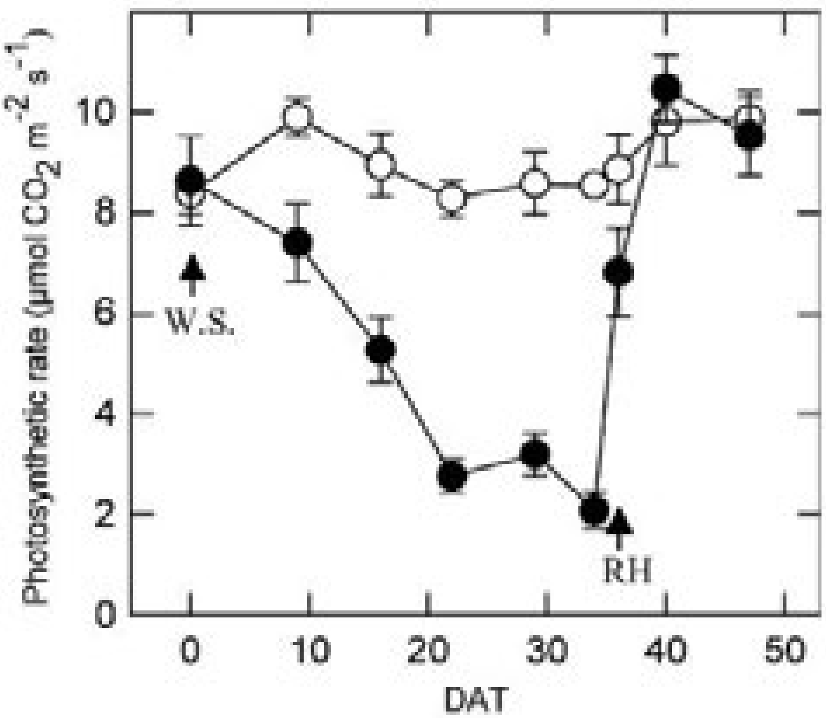


Figure 5. Photosynthetic rate (a) in fully expanded leaves in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Data are means ± SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

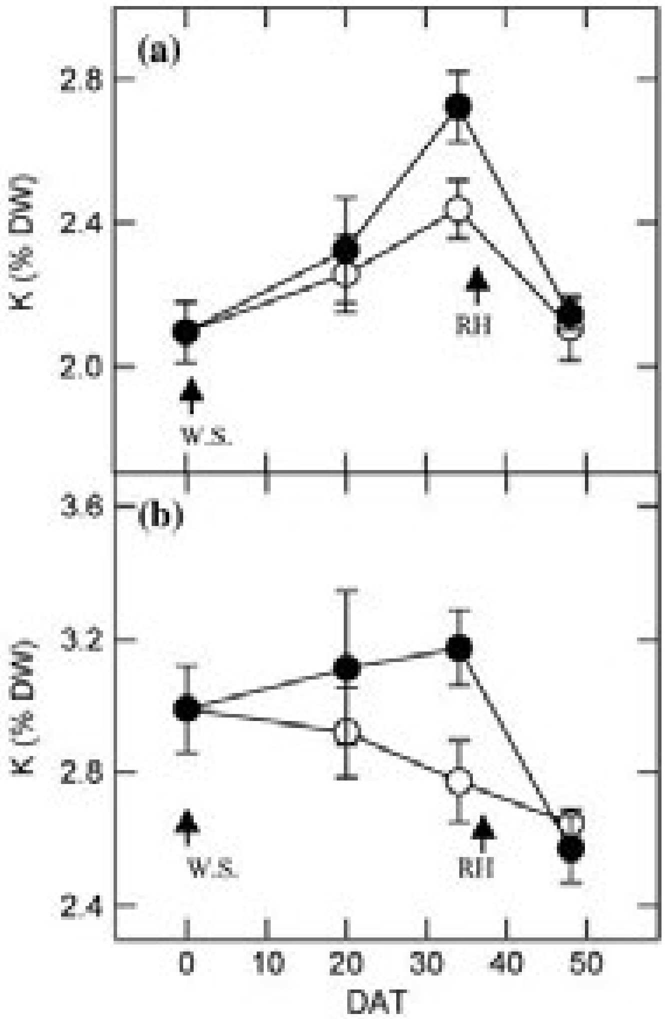


Figure 7. Potassium content in leaf (A) and root (B) tissues in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Each value is the mean of at least three independent measurements ($n \geq 3$) ± SE. DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

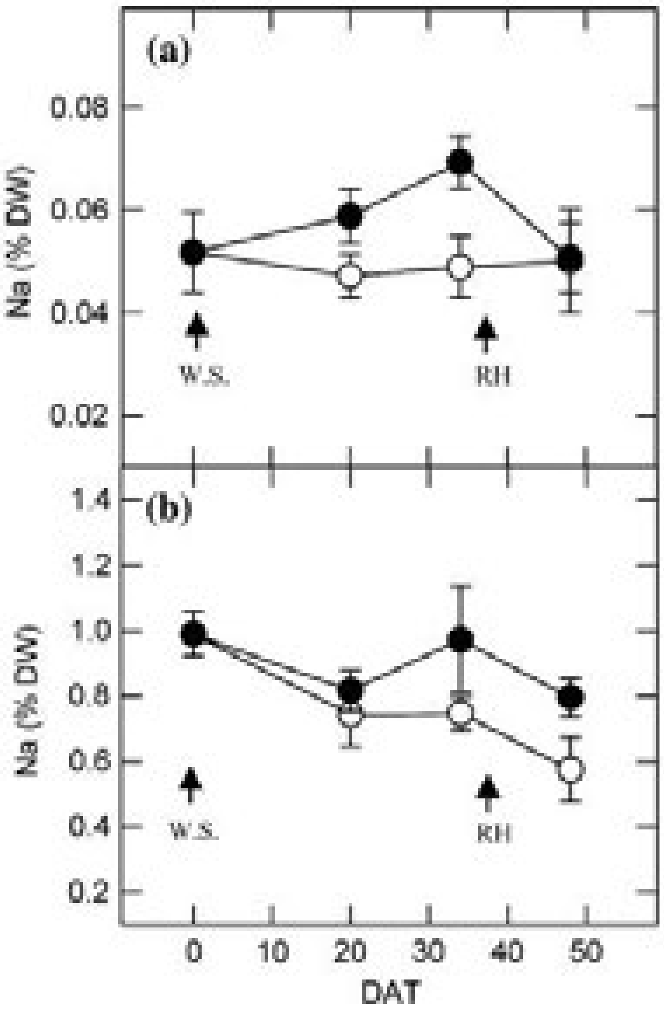


Figure 8. Sodium content in leaf (A) and root (B) tissues in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Each value is the mean of at least three independent measurements ($n \geq 3$) ±SE. DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

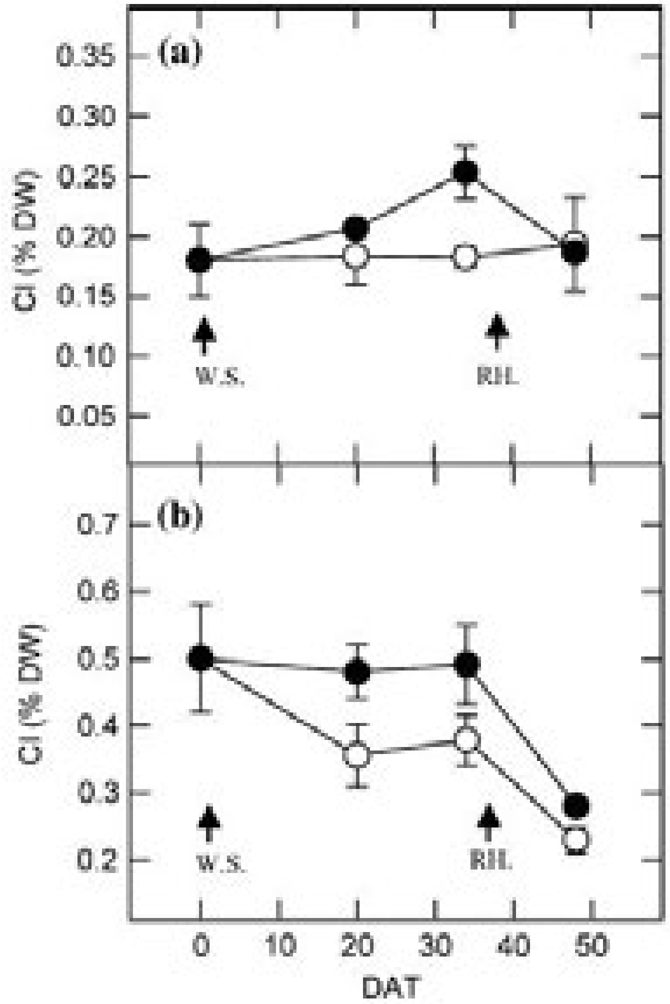


Figure 9. Chloride content in leaf (a) and root (b) tissues in papaya seedlings. Treatments were: regular irrigated plants (○) and non-irrigated plants during 34 days followed by re-watering until the end of experiment (●). Each value is the mean of at least three independent measurements ($n \geq 3$) ±SE. DAT = days after treatment. WS: Water Stress. RH: Re-hydration.

In conclusion, papaya plants subjected to water stress showed a tendency to accumulate ions such as K^+, Na^+ and Cl^-. The ion increases that were registered on per DW basis might apparently contribute for osmotic adjustment, enhancing water stress tolerance of these plants. The data also indicate that stress tolerance was not mediated through the reduction of leaf abscission, the detention of growth or decrease of net CO_2 assimilation. Re-irrigation induced plant morphological and physiological recovery without irreversible effects of water stress.

Plant Growth Regul (2007) 53:43–51
DOI 10.1007/s10725-007-9202-2

ORIGINAL PAPER

Hormonal changes in papaya seedlings subjected to progressive water stress and re-watering

Jalel Mahouachi · Vicent Arbona ·
Aurelio Gómez-Cadenas

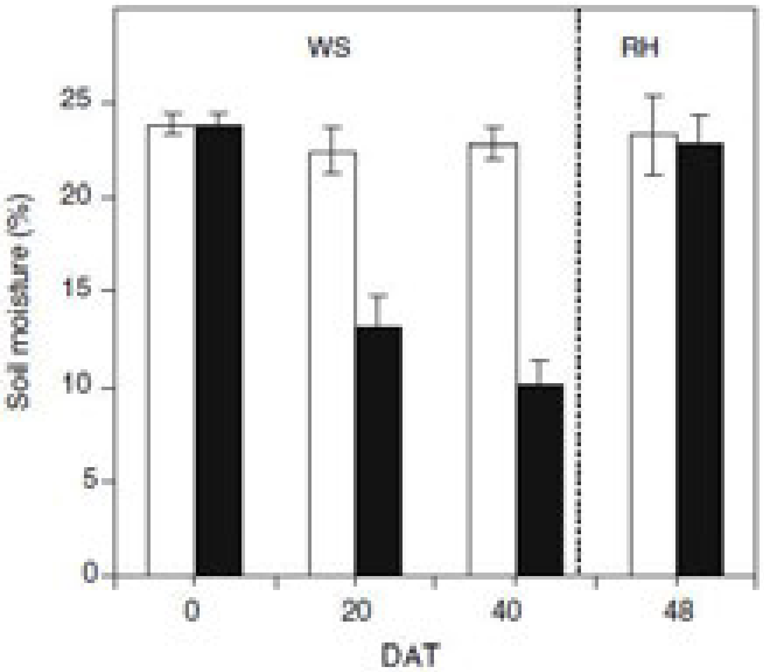


Fig. 1 Soil moisture (%) in irrigated (□) and non-irrigated pot soils (■) of papaya seedlings. In water-stressed soils, irrigation was released during 40 days and re-established thereafter until the end of experiment. Data are means ± SE and each value was determined by three TDR probes with three replicates per treatment ($n \geq 9$) (one probe per pot). DAT = days after treatment. WS: water stress. RH: rehydration

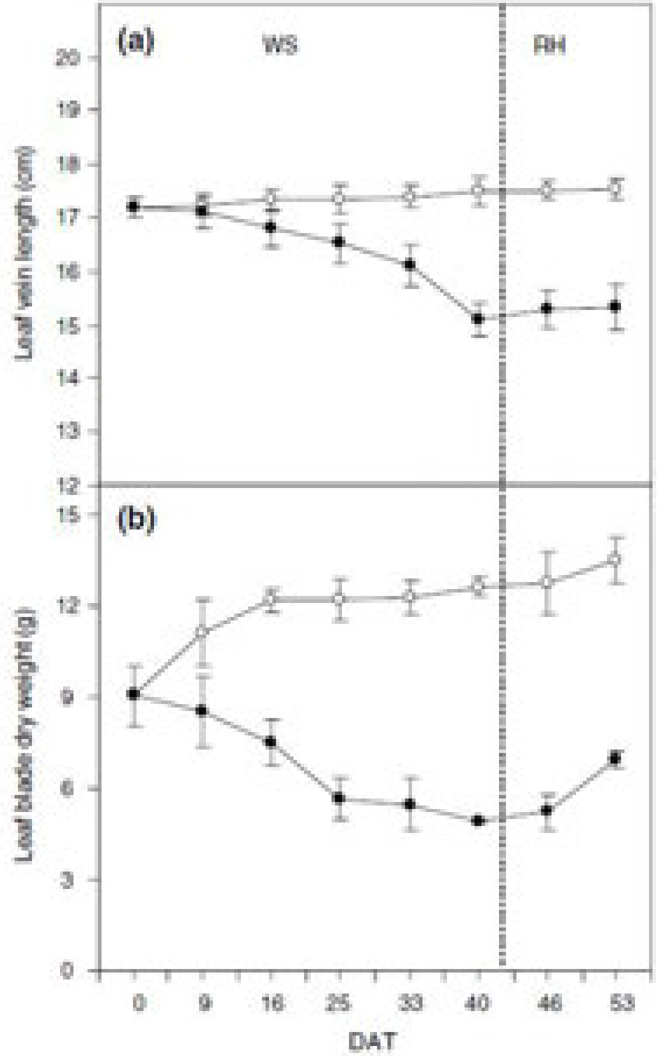


Fig. 2 Principal leaf vein length (a) and leaf blade dry weight (b) in papaya seedlings. Treatments were: regular irrigated plants (○) and water-stressed plants during 40 days followed by re-watering until the end of experiment (●). Data are means ± SE and each value was determined from at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: water stress. RH: rehydration

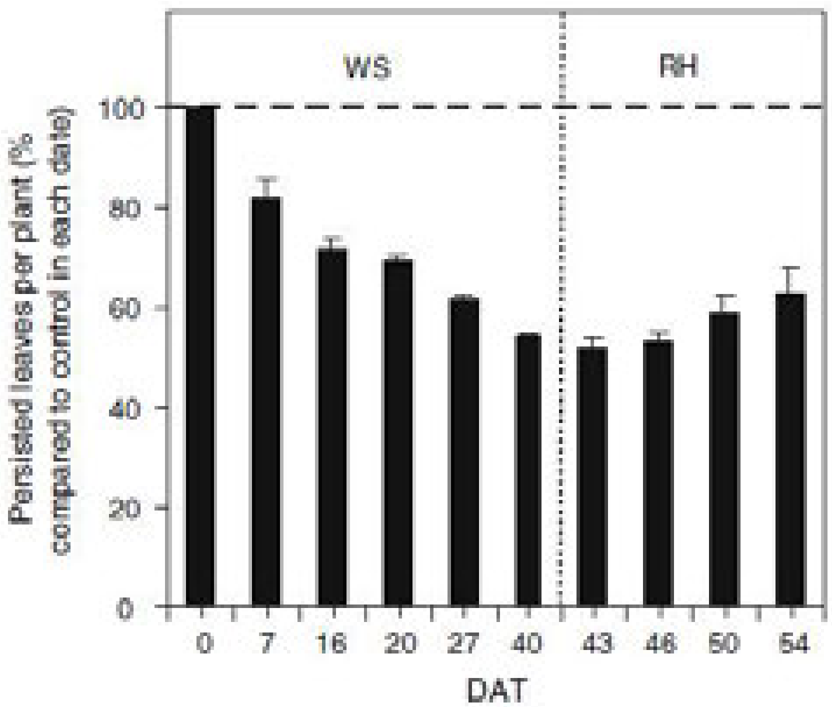


Fig. 3 Percentage of leaves present in papaya plants subjected to WS during 40 days and subsequent RH (■). Data are expressed as percentages with respect to control plants (– – – –) in each date. Data are means ± SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: water stress. RH: rehydration

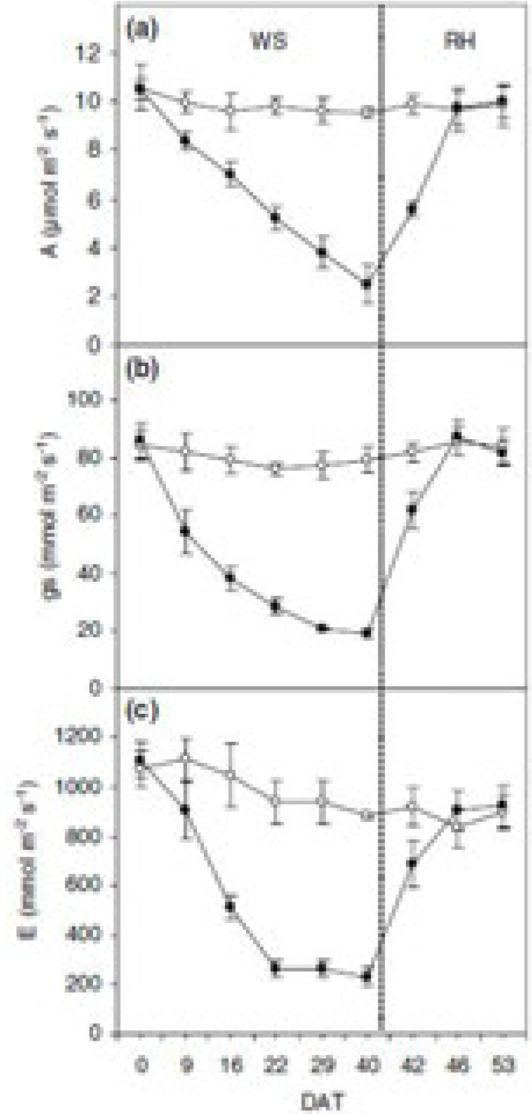


Fig. 4 Photosynthetic rate (A, (a)), stomatal conductance (gs, (b)) and transpiration rate (E, (c)) in fully expanded leaves in papaya seedlings. Treatments were: regular irrigated plants (○) and water-stressed plants during 40 days followed by re-watering until the end of experiment (●). Data are means ± SE and each value was determined in at least three different plants with three replicates per treatment ($n \geq 9$). DAT = days after treatment. WS: water stress. RH: rehydration

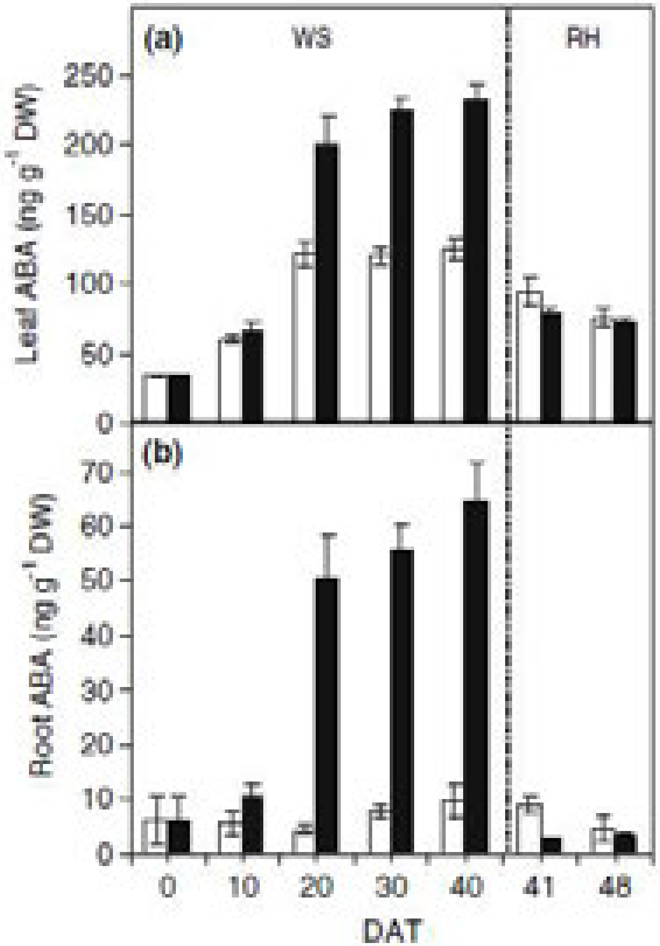
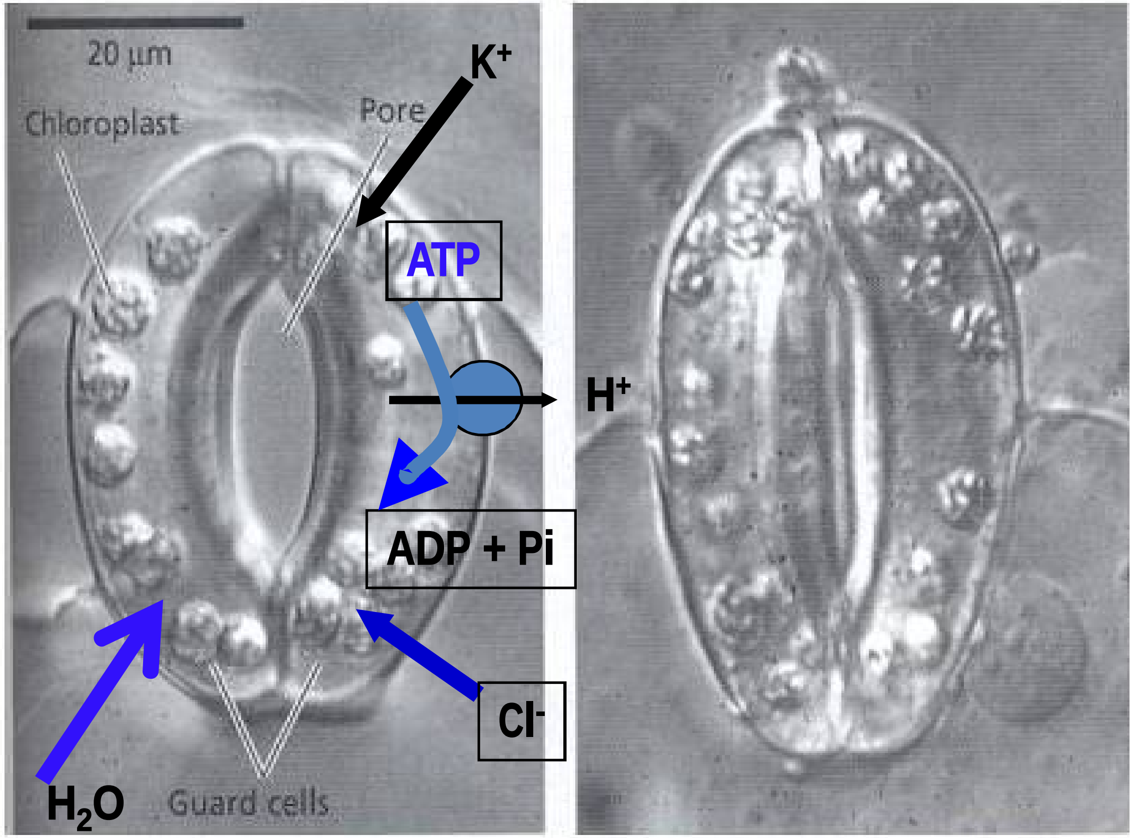
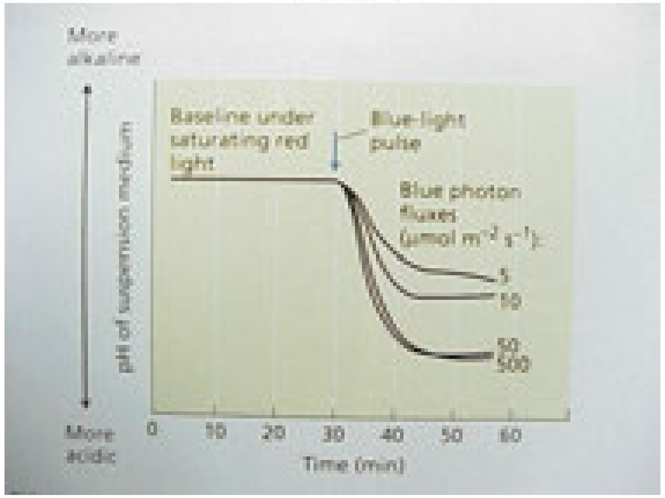
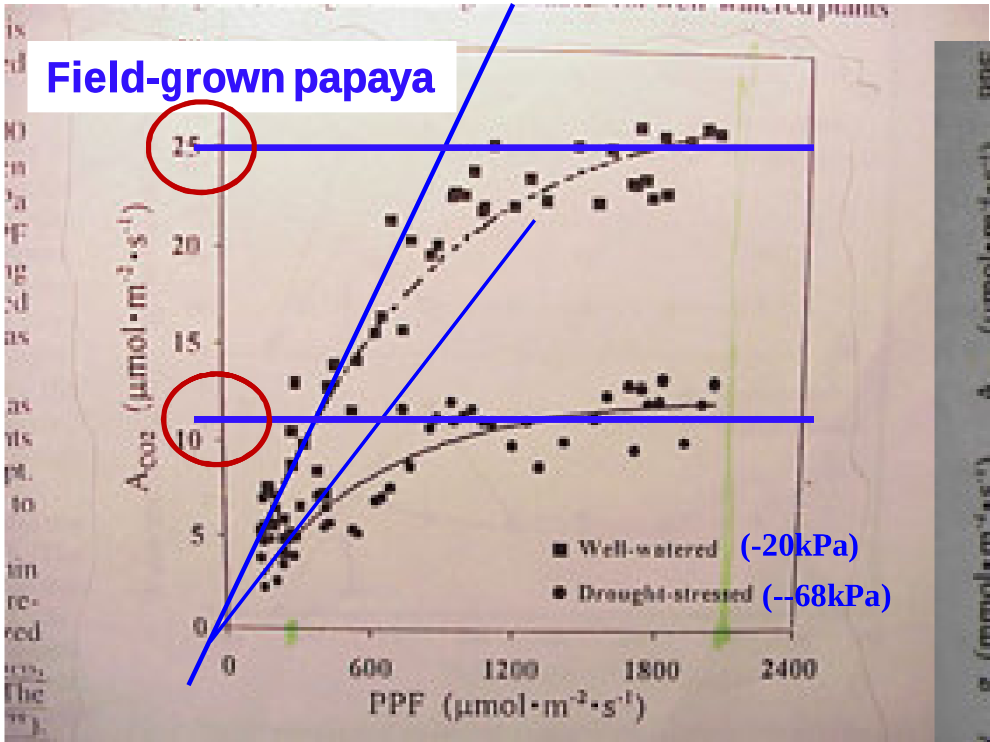
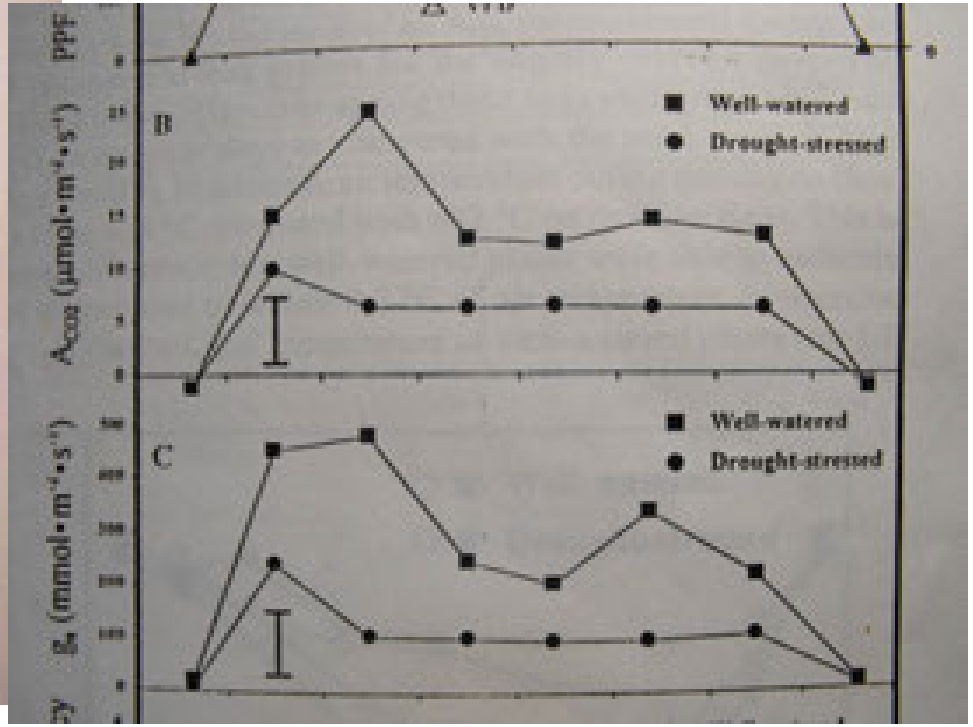


Fig. 5 Abscisic acid (ABA) levels in leaves (a) and roots (b) from well-watered plants (□) and from plants subjected to WS during 40 days and subsequent RH (■) in papaya seedlings. Each value is the mean of at least three independent measurements ($n \geq 3$) ±SE. DAT = days after treatment. WS: water stress. RH: rehydration









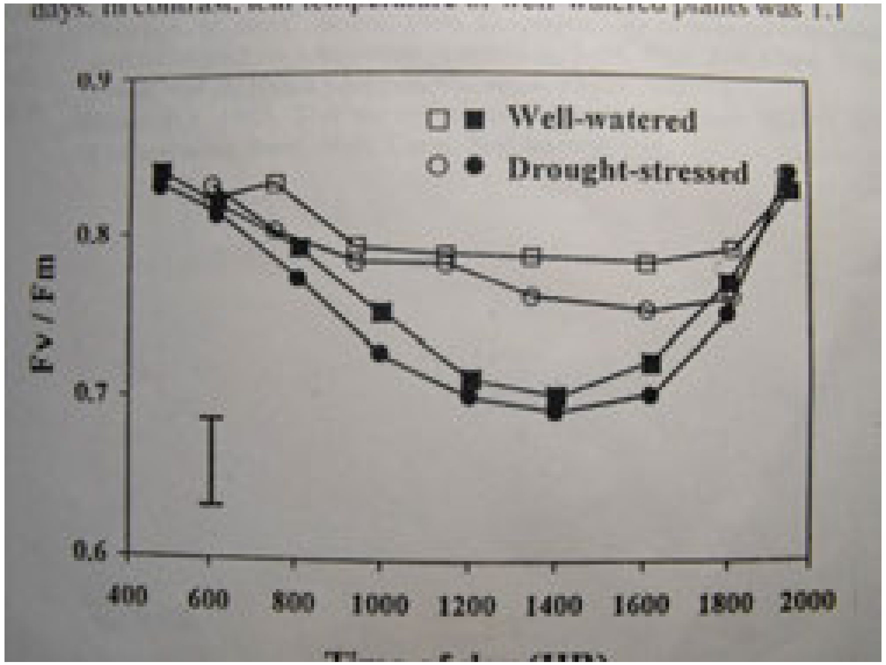
21 Mar. 1996, when ψ_m was –62 kPa for the drought-stressed

obtained on 29 Mar., when ψ_m was –68 kPa for the drought

Treatment		ϕ_i (mol CO_2/mol incident quanta)
Control	Tainung	0.039 ± 0.001
Drought		0.025 ± 0.001**
Control	Red Lady	0.044 ± 0.001
Drought		0.024 ± 0.001**
Control	Sunrise	0.040 ± 0.001
Drought		0.024 ± 0.001**

**Significant at $P = 0.01$.

apidly increased to an early or mid



Marler e Mickelbart, 1998

Strategies to increase effective use of water in papaya

-Regulated deficit irrigation (RDI)
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Partial rootzone drying (PRD) and regulated deficit irrigation (RDI) effects on stomatal conductance, growth, photosynthetic capacity, and water-use efficiency of papaya[☆]

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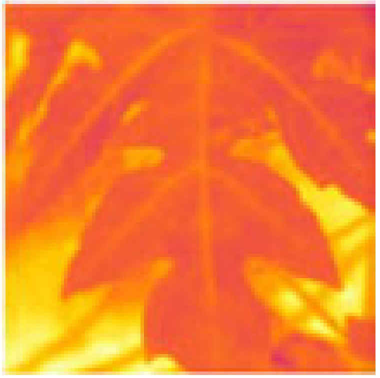
Strategies to increase effective use of water in papaya

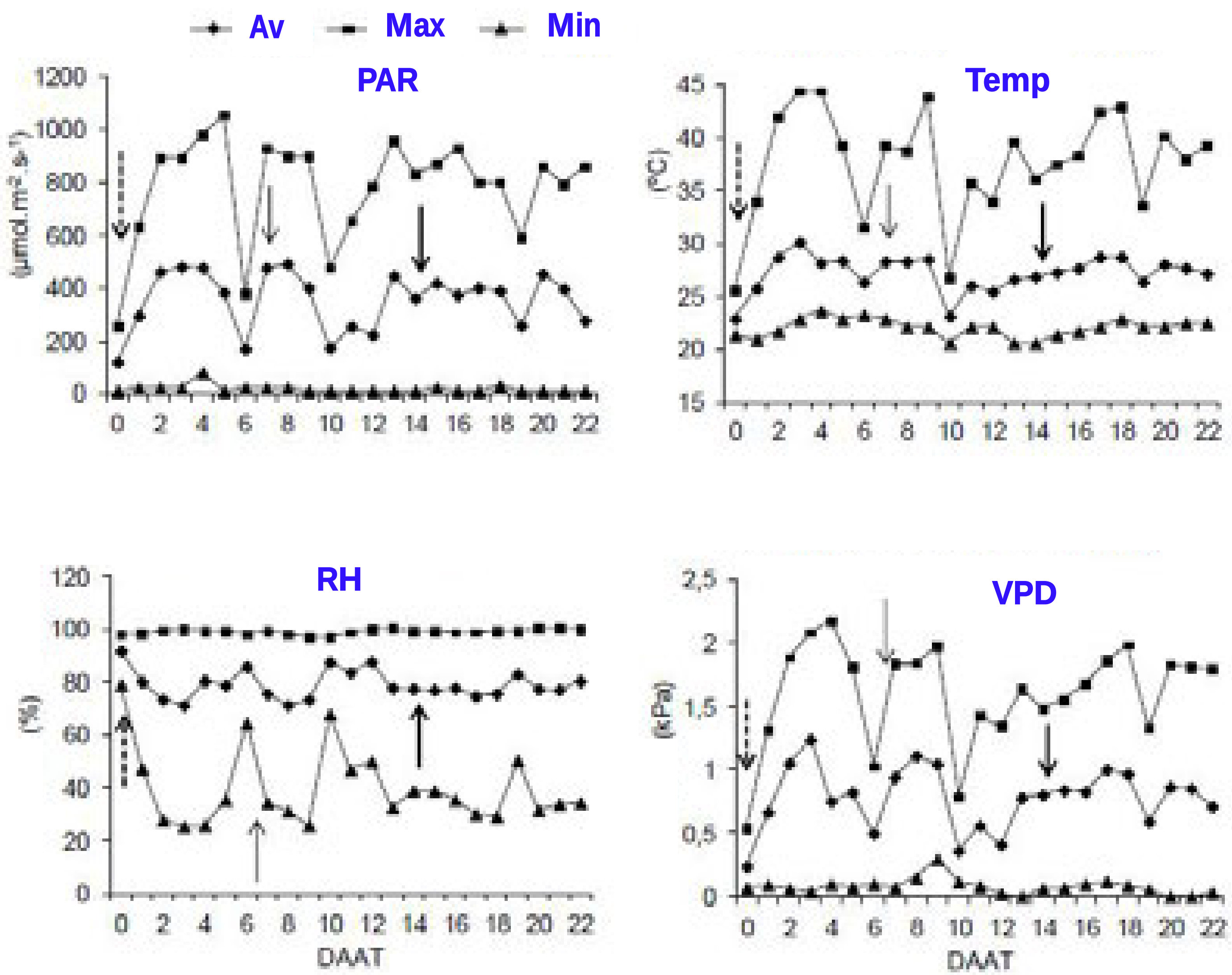
-Regulated deficit irrigation (RDI)
-Partial rootzone drying (PRD)

15L pots
Substrate soil, sand and cattle manure (2:1:2)
The plants were kept at field capacity (FC) until they were 96 days old.





-Gas exchange
-Chlorophyll fluorescence
-Growth (central vein lenght, root dry biomass, stem dry biomass, leaf dry biomass, total dry biomass, root volume)
-Proline
-Carbon isotope discrimination
-Agronomic water use efficiency
-Thermal imaging



Av
Max
Min
PAR
(µmol.m-2.s-1)
Temp
(°C)
RH
(%)
DAAT
VPD
(kPa)
DAAT

The plants were kept at field capacity (FC) until they were 96 days old.

Table 1
Timeline of irrigation treatments.

		Days after irrigation treatment application																					
Treatment	Pot	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
FI	1												100% FC										
	2												100% FC										
PRD	1				100% FC														100% FC				
	2												100% FC										
RDI	1												50% FC										
	2												50% FC										
NI	1																		100% FC				
	2																		100% FC				

Full irrigated (FI); partial-root-zone drying (PRD); regulated deficit irrigation (RDI); non-irrigated (NI). Dark-grey represents the period of days in which irrigation was applied at 100% of field capacity (FC). The light grey represents the days with irrigation at 50% of field capacity. The white color represents the period of time with no irrigation.

Table 1
Total volume of water applied, and volume applied per day of greenhouse-grown papaya (*Carica papaya* L.) in splitroot pots with four different irrigation treatments: full irrigated (FI), Partial Rootzone Drying (PRD), Regulated Deficit Irrigation (RDI), and non-irrigated followed by 6 days of FI (NI-gh).

Treatment	Total volume of water applied (L)	Volume of water applied per day (L)
FI	47.50	2.3
PRD	23.8	1.1
RDI	23.8	1.1
NI-gh	21.3	1.0

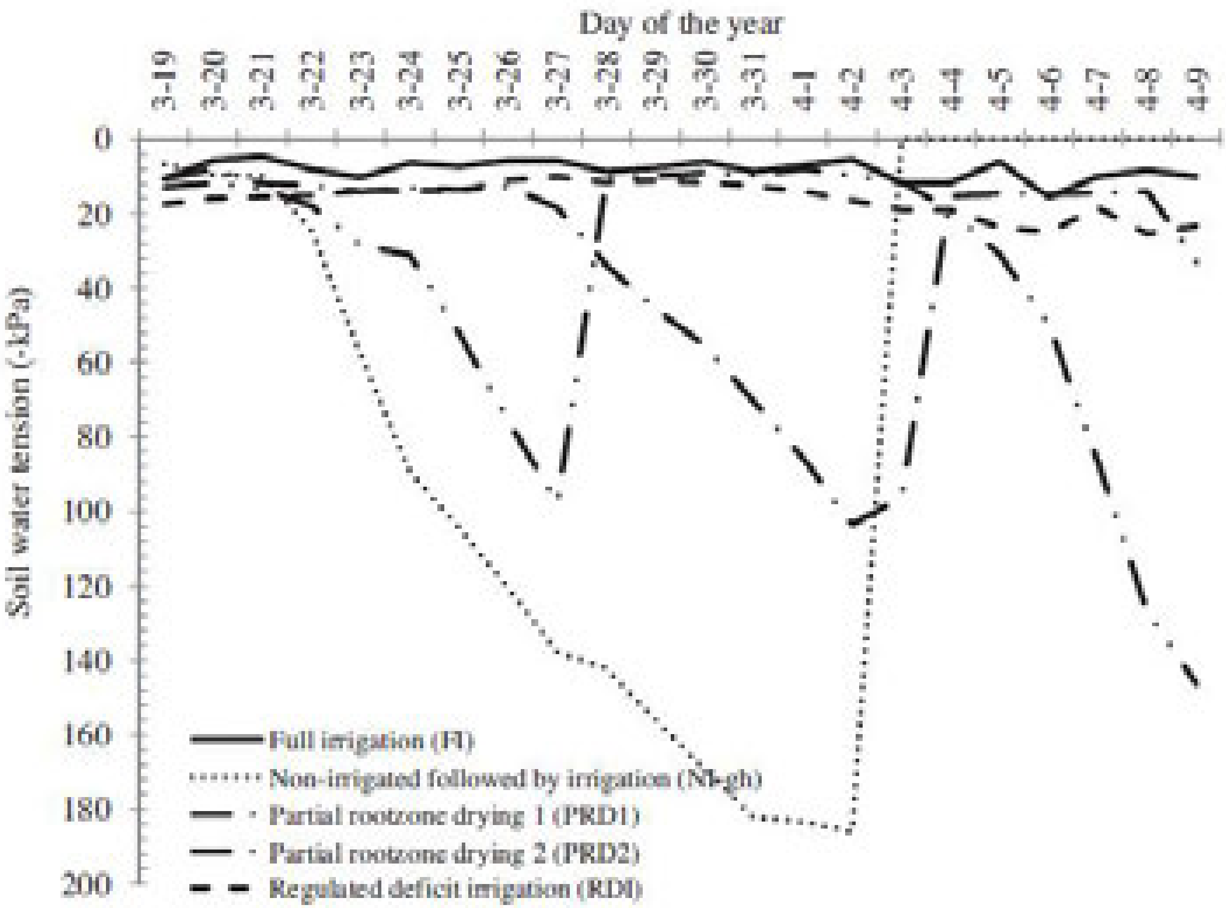


Fig. 1. Daily soil water potential (−kPa) planted with 'Grand Golden' papaya with four irrigation treatments. PRD-1 and PRD-2 indicate the two sides of the PRD pots.

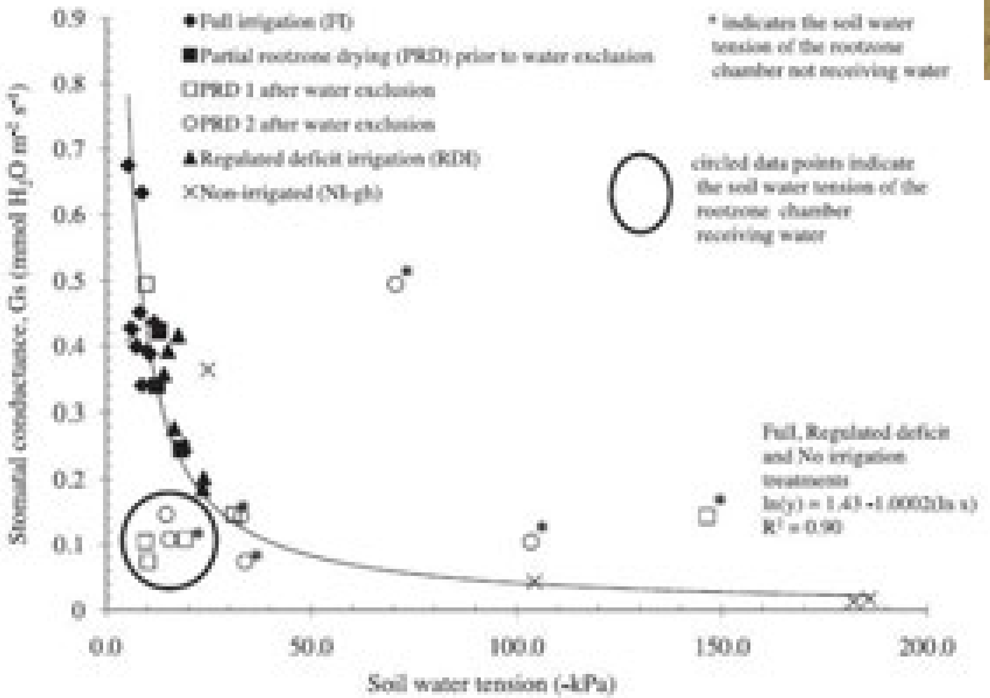
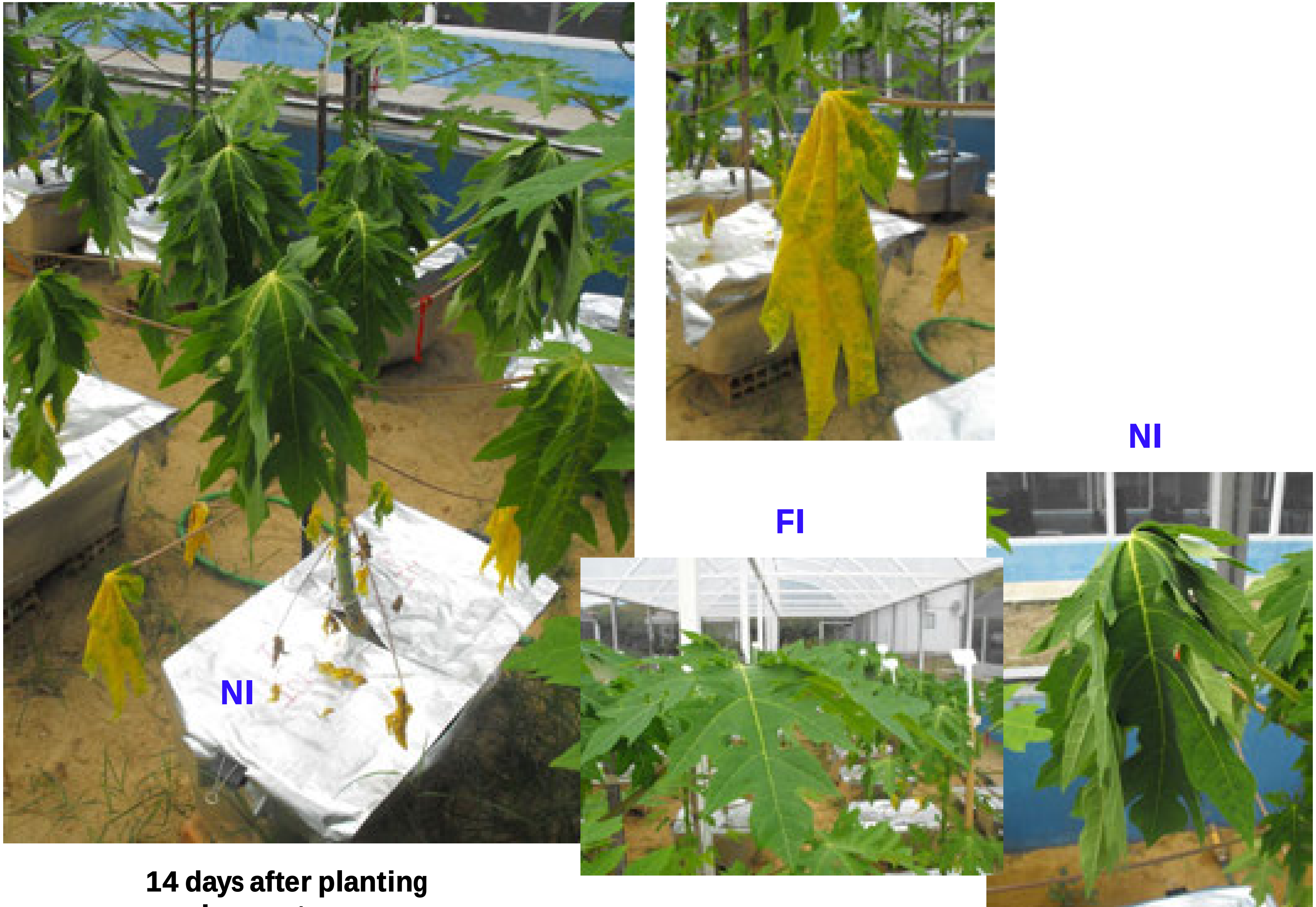


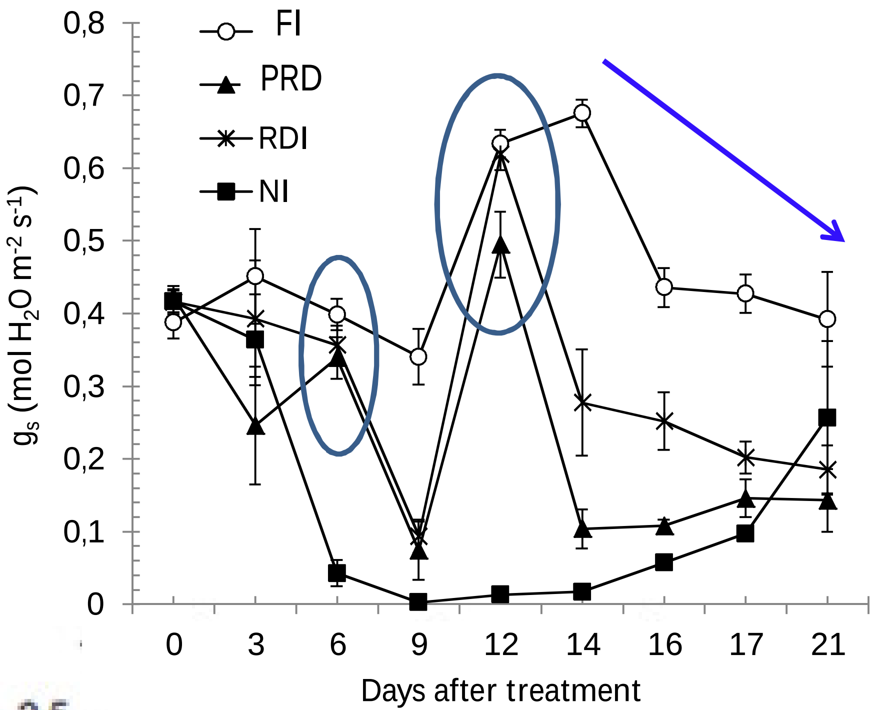
Fig. 10. Relationship between stomatal conductance and soil water potential in papaya in four irrigation treatments in the greenhouse.

NI **PRD**

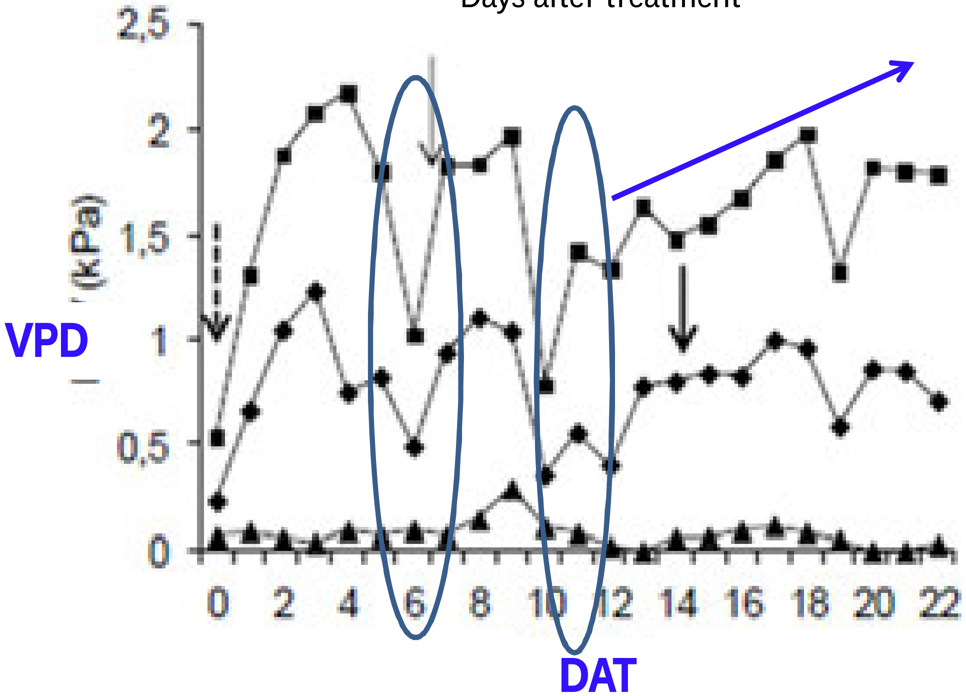
14 days after planting maximum stress



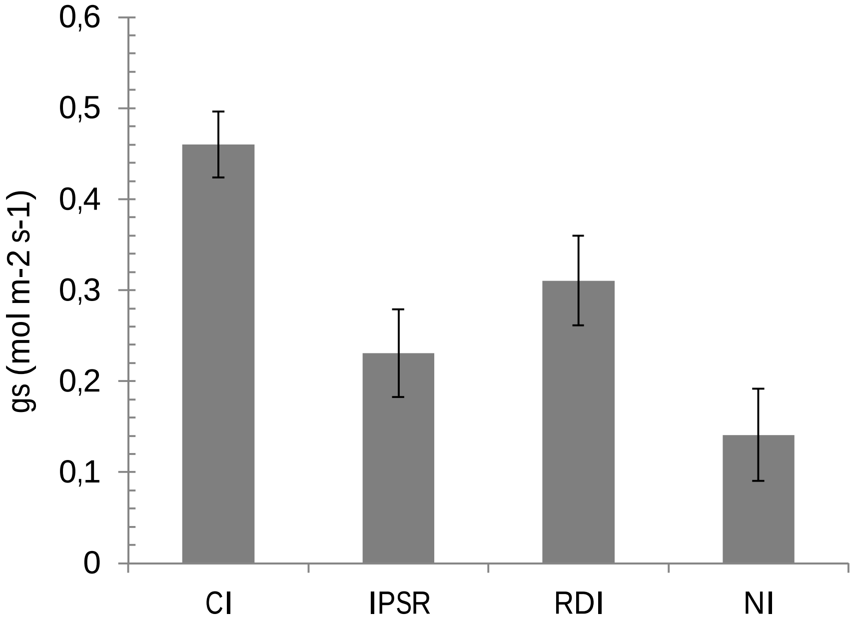
14 days after planting
maximum stress



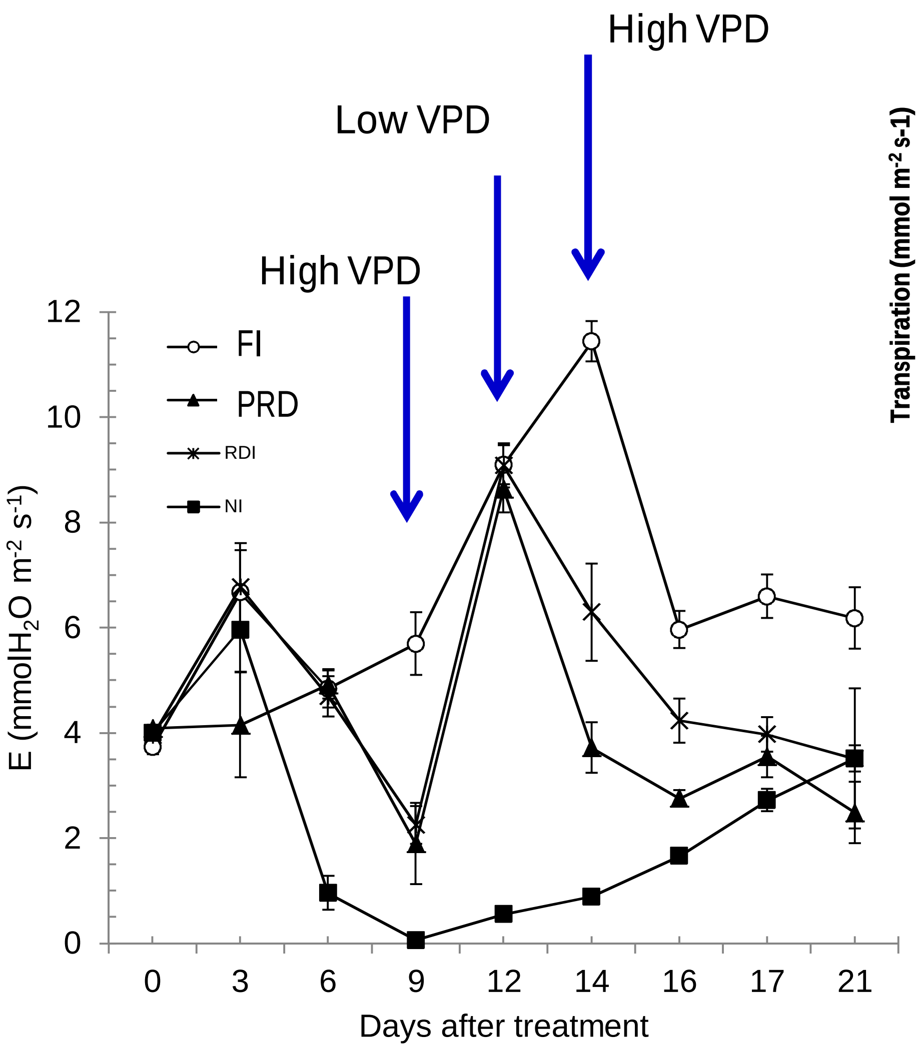
FI
PRD
RDI
NI
g_s (mol H_2O m^{-2} s^{-1})
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0 3 6 9 12 14 16 17 21
Days after treatment



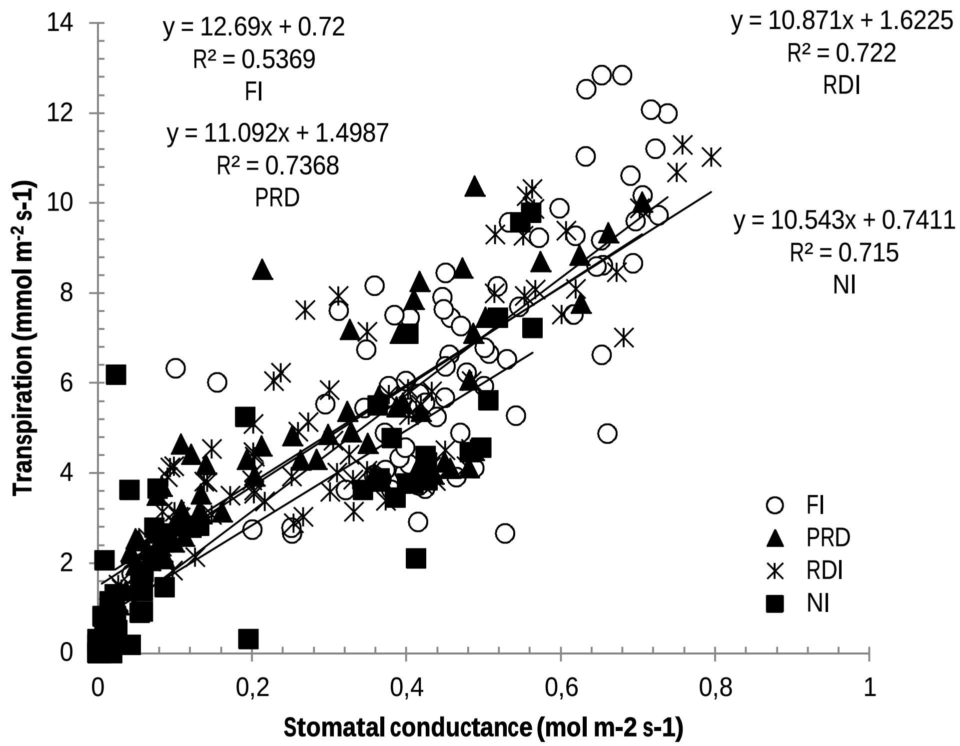
VPD
(kPa)
2,5
2
1,5
1
0,5
0
0 2 4 6 8 10 12 14 16 18 20 22
DAT



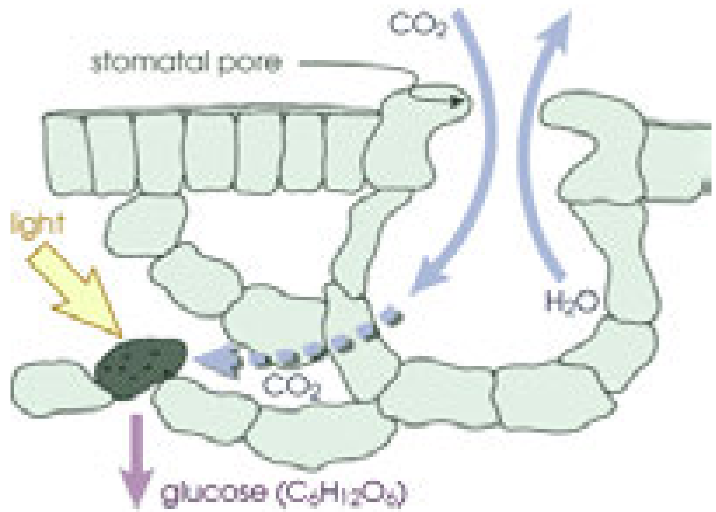
gs (mol m-2 s-1)
0,6
0,5
0,4
0,3
0,2
0,1
0
CI
IPSR
RDI
NI



High VPD
Low VPD
High VPD
FI
PRD
RDI
NI
E (mmolH2O m-2 s-1)
Days after treatment



y = 12.69x + 0.72
R² = 0.5369
FI
y = 11.092x + 1.4987
R² = 0.7368
PRD
y = 10.871x + 1.6225
R² = 0.722
RDI
y = 10.543x + 0.7411
R² = 0.715
NI
FI
PRD
RDI
NI
Transpiration (mmol m-2 s-1)
Stomatal conductance (mol m-2 s-1)



stomatal pore
CO2
light
H2O
CO2
glucose (C6H12O6)

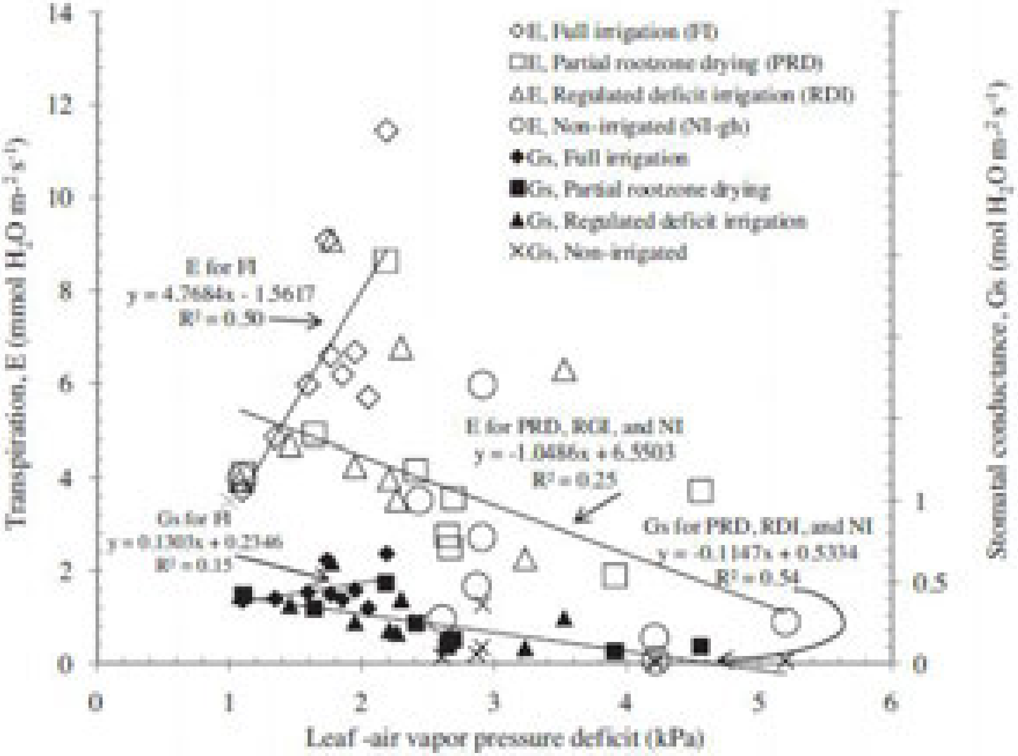
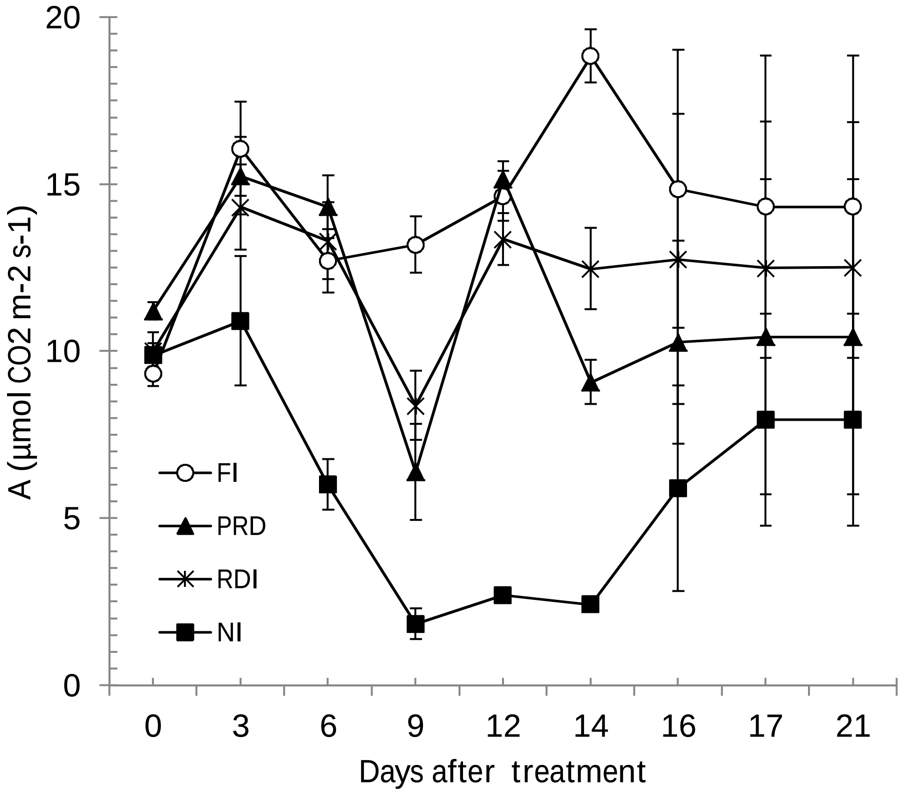
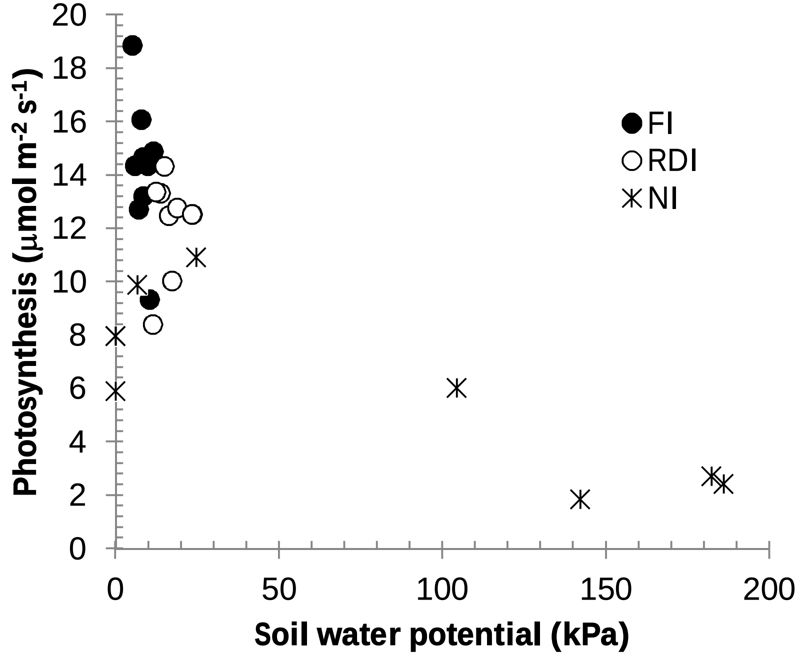


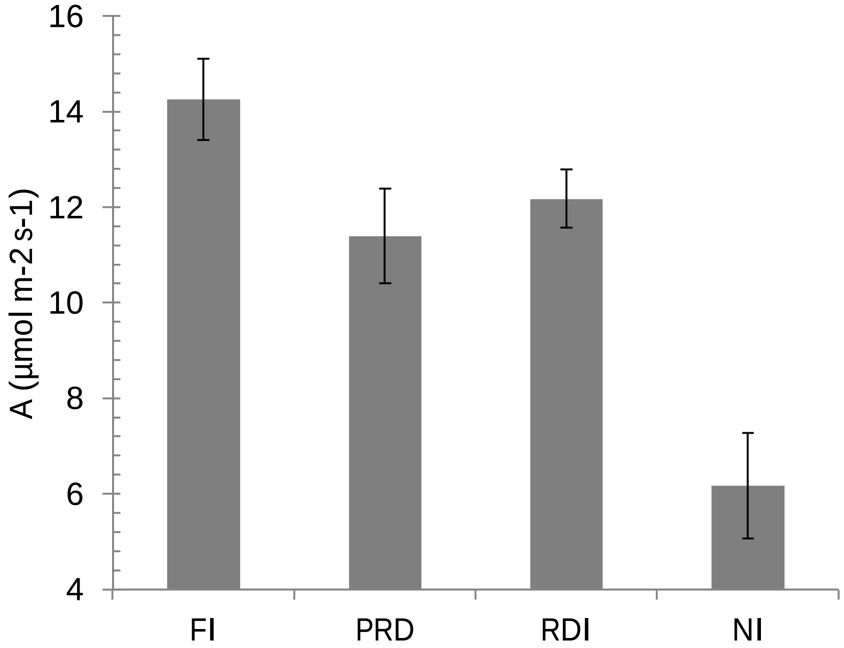
Fig. 6. Relationship of leaf–air vapor pressure deficit to transpiration and stomatal conductance in papaya in four irrigation treatments in a greenhouse.



A (µmol CO2 m-2 s-1)
20
15
10
5
0
FI
PRD
RDI
NI
0
3
6
9
12
14
16
17
21
Days after treatment



Photosynthesis (µmol m-2 s-1)
20
18
16
14
12
10
8
6
4
2
0
FI
RDI
NI
0
50
100
150
200
Soil water potential (kPa)



A (µmol m-2 s-1)
16
14
12
10
8
6
4
FI
PRD
RDI
NI