MEDSTRESS
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Università di Pisa
Corso di Dottorato di Ricerca in
Scienze Agrarie, Alimentari e Agro-ambientali
PhD Program on Agriculture, Food and Environment

How sensitive is *Quercus cerris* to combined ozone and drought stress?

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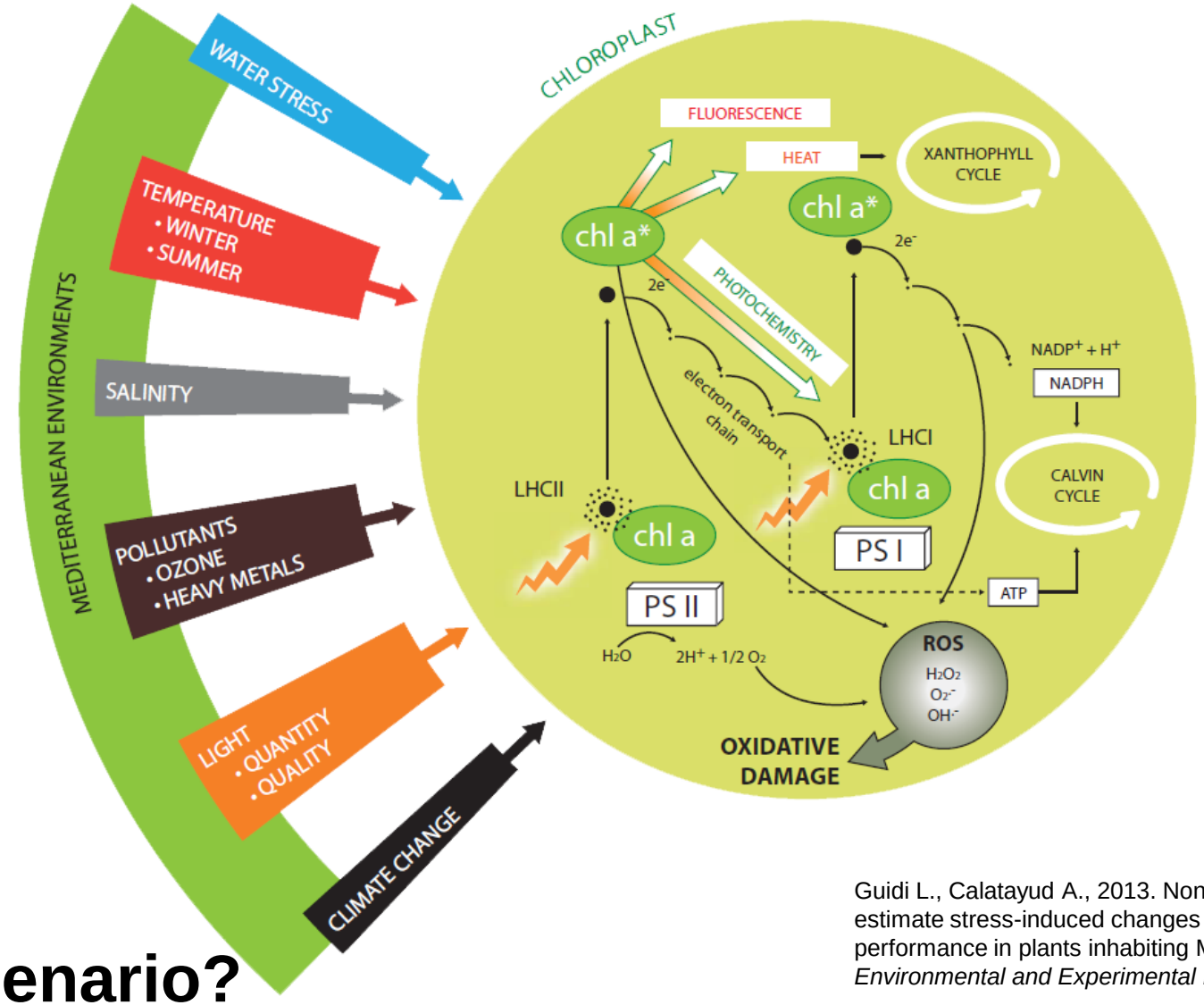
Monitoring of Mediterranean plants health is necessary



2050 scenario?

Guidi L., Calatayud A., 2013. Non-invasive tools to estimate stress-induced changes in photosynthetic performance in plants inhabiting Mediterranean areas. *Environmental and Experimental Botany, in press*

Aim of the work

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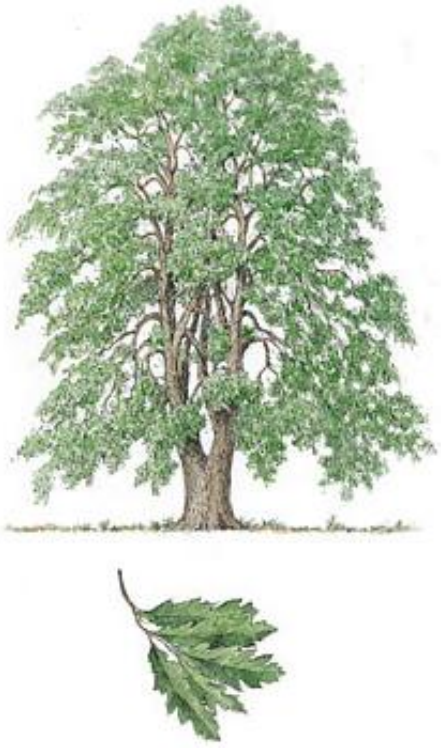
- Responses of the Mediterranean deciduous *Quercus cerris* to combined stress (ozone and drought) to simulate a 2050 global climate change scenario



- Combination of ozone and drought = ozone and drought applied individually?

Materials and methods

- June-August 2013 (11 weeks)
- Three-year-old seedlings
- Four exposure chambers:
  1. Control
  2. Drought stress
  3. Ozone stress
  4. Combined stress (Drought x Ozone)
- O_3 concentration: 80-100 ppb, 5 h d^{-1}
- Drought stress: 30% of effective evapotranspiration

PHYSIOLOGICAL ANALYSES:

•Gas exchanges

•Chlorophyll *a* fluorescence

•Pre-dawn leaf water potential

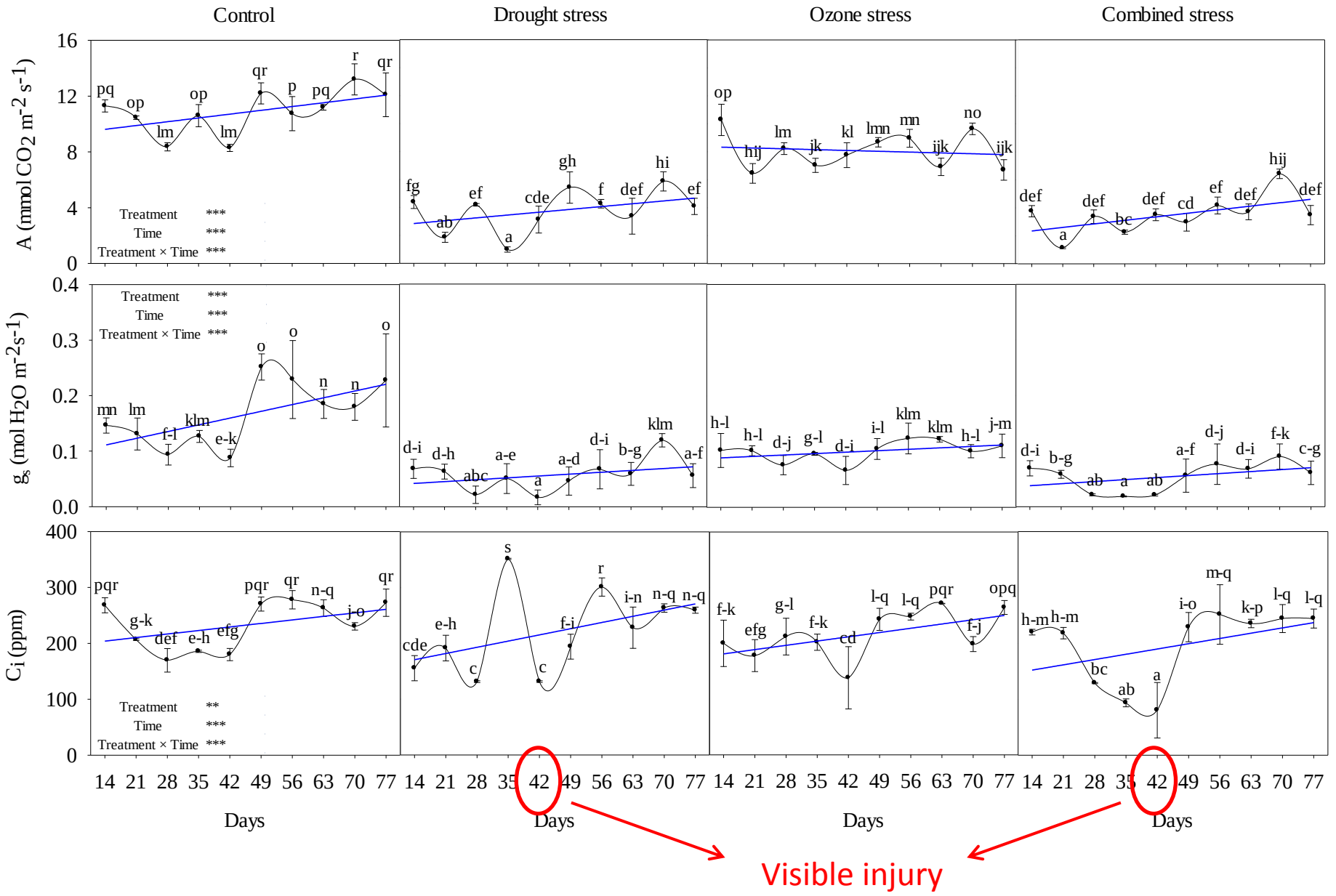
•Growth parameters and biomass

BIOCHEMICAL ANALYSES:

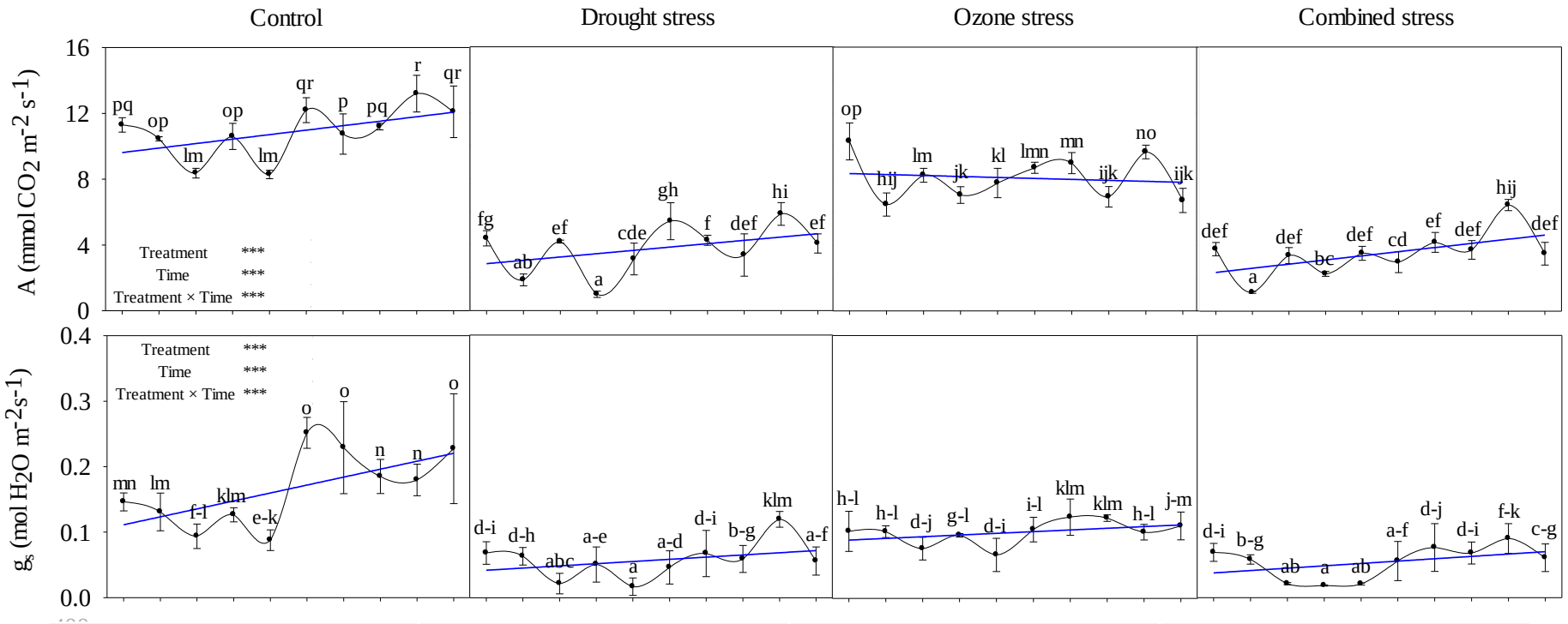
•Lipid peroxidation (MDA)

•Proline

Gas-exchanges (weekly profile)



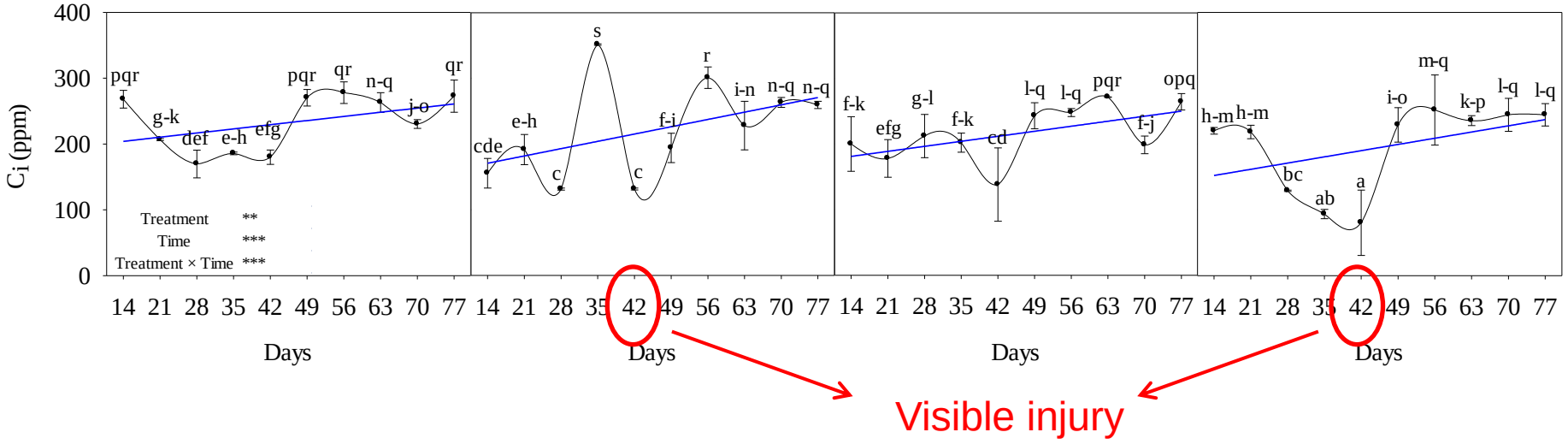
Gas-exchanges (weekly profile)



	Drought stress	Ozone stress	Combined stress
A	From the 2nd week	From the 7th week	From the 2nd week
	↓ - 65.3%	↓ - 25.6%	↓ - 67.9%
g_s	From the 2nd week	From the 7th week	From the 2nd week
	↓ - 65.7%	↓ - 39.6%	↓ - 67.5%

Gas-exchanges (weekly profile)

	Drought stress	Ozone stress	Combined stress
C_i	From the 7th week	From the 7th week	From the 8th week



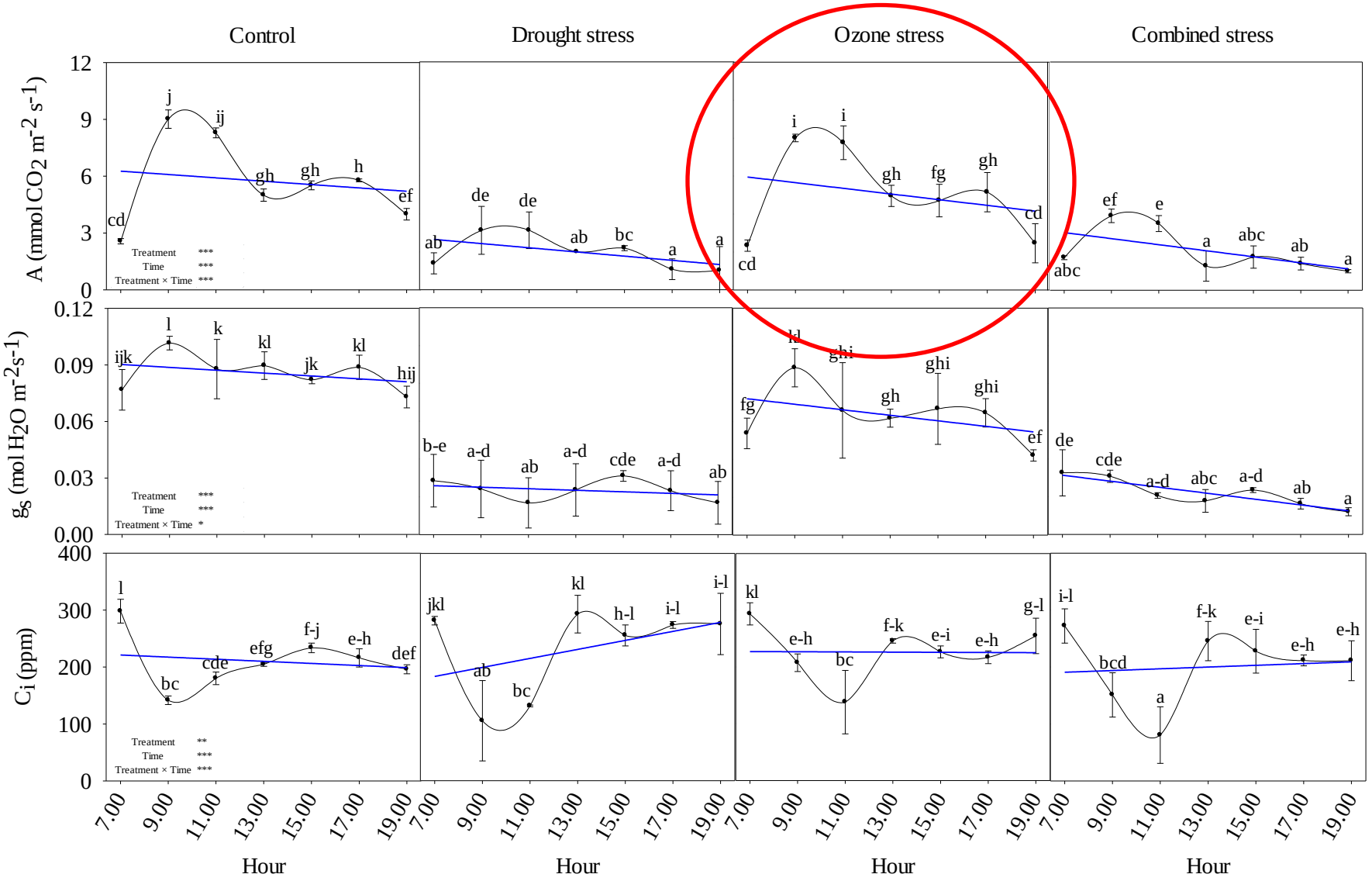
Gas-exchanges (weekly profile)

	Drought stress	Ozone stress	Combined stress
A	From the 2nd week	From the 7th week	From the 2nd week
	↓ - 65.3%	↓ - 25.6%	↓ - 67.9%
g_s	From the 2nd week	From the 7th week	From the 2nd week
	↓ - 65.7%	↓ - 39.6%	↓ - 67.5%
C_i	From the 7th week	From the 7th week	From the 8th week
	=	=	=

- Decrease of net photosynthesis was twinned with stomatal and biochemical limitations (or damage)
- Drought should be considered more harmful than ozone
- Combined stress did not show significant changes in comparison to drought stressed individuals

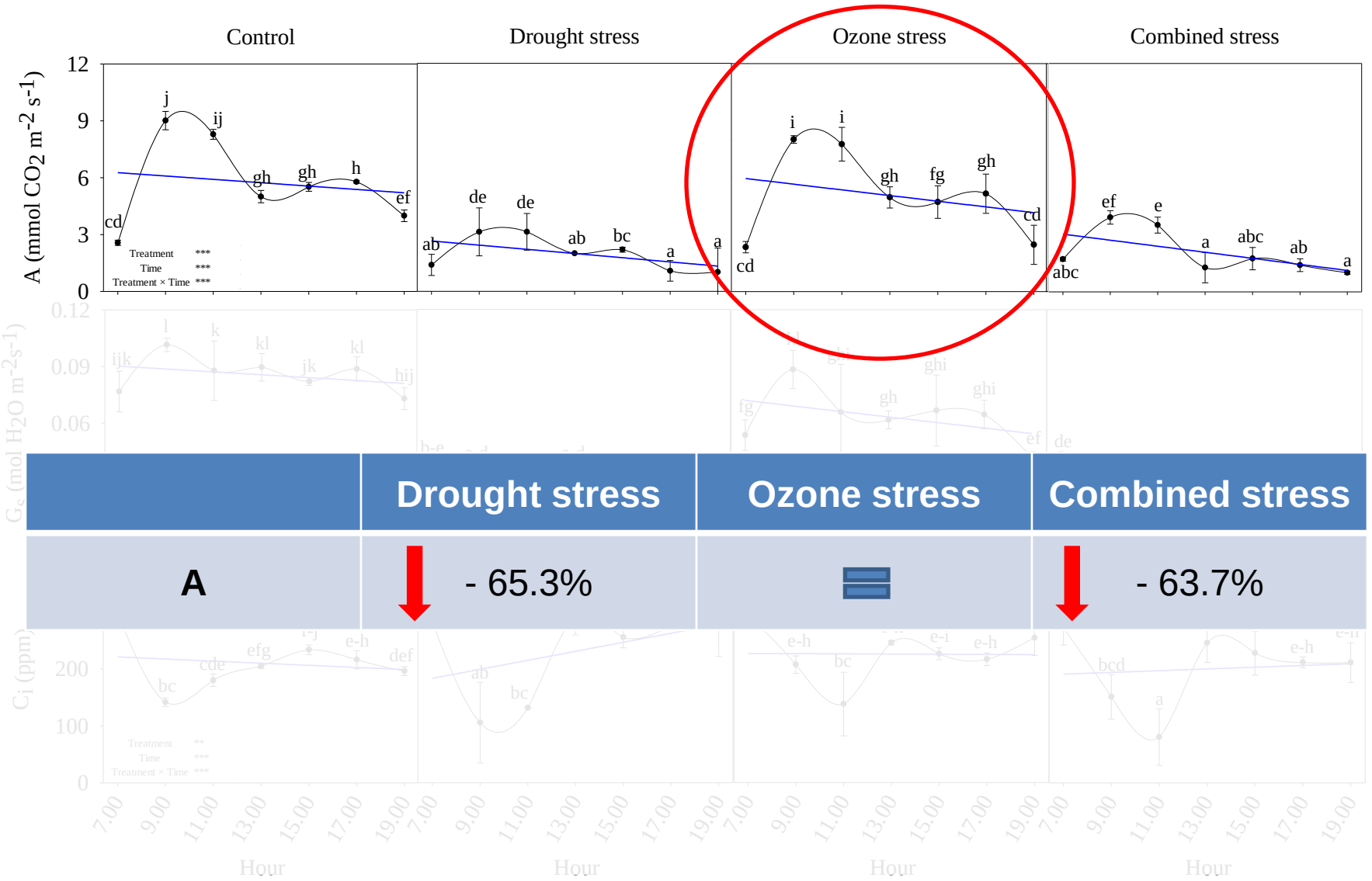
Gas-exchanges (daily profile)

VI week: visible injury observed



Gas-exchanges (daily profile)

VI week: visible injury observed

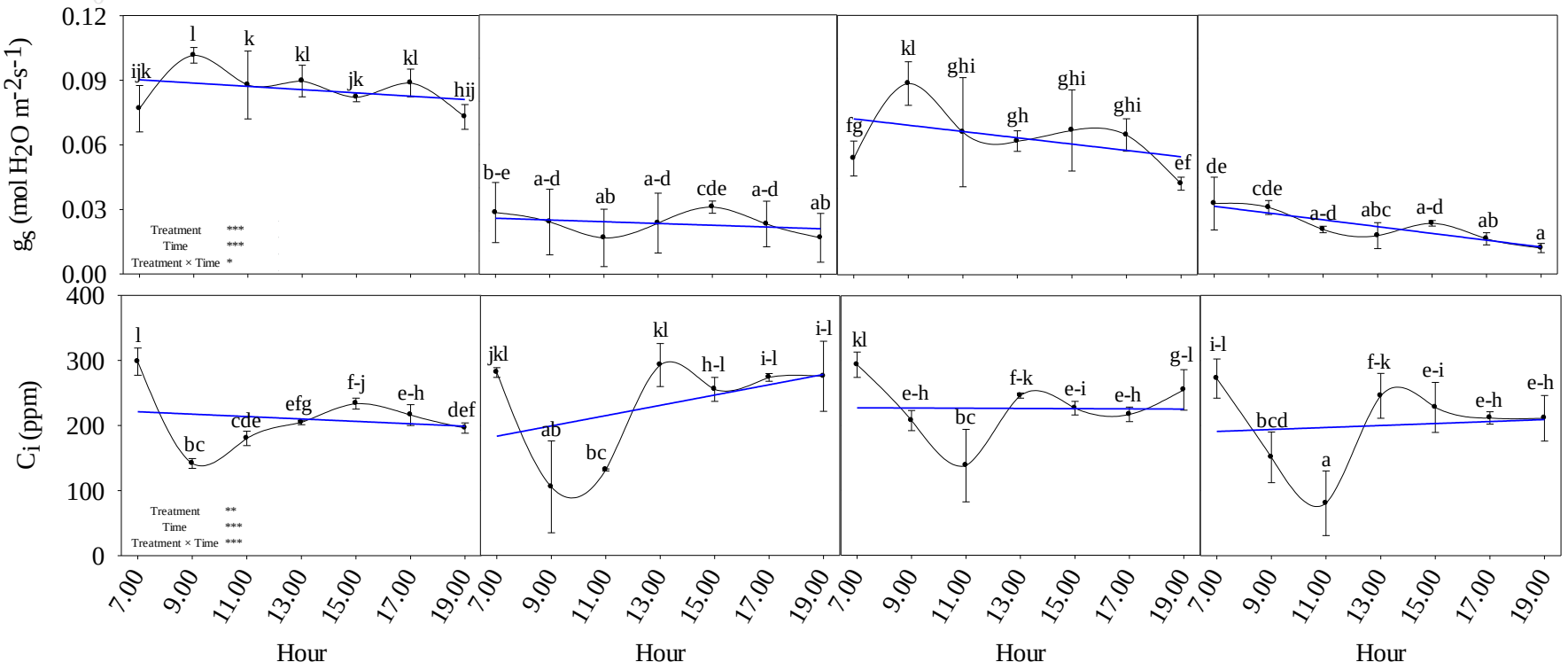


	Drought stress	Ozone stress	Combined stress
A	↓ - 65.3%	=	↓ - 63.7%

Gas-exchanges (daily profile)

VI week: visible injury observed

	Drought stress	Ozone stress	Combined stress
g_s	↓ - 72.6%	↓ - 26.0%	↓ - 74.3%
C_i	=	=	=

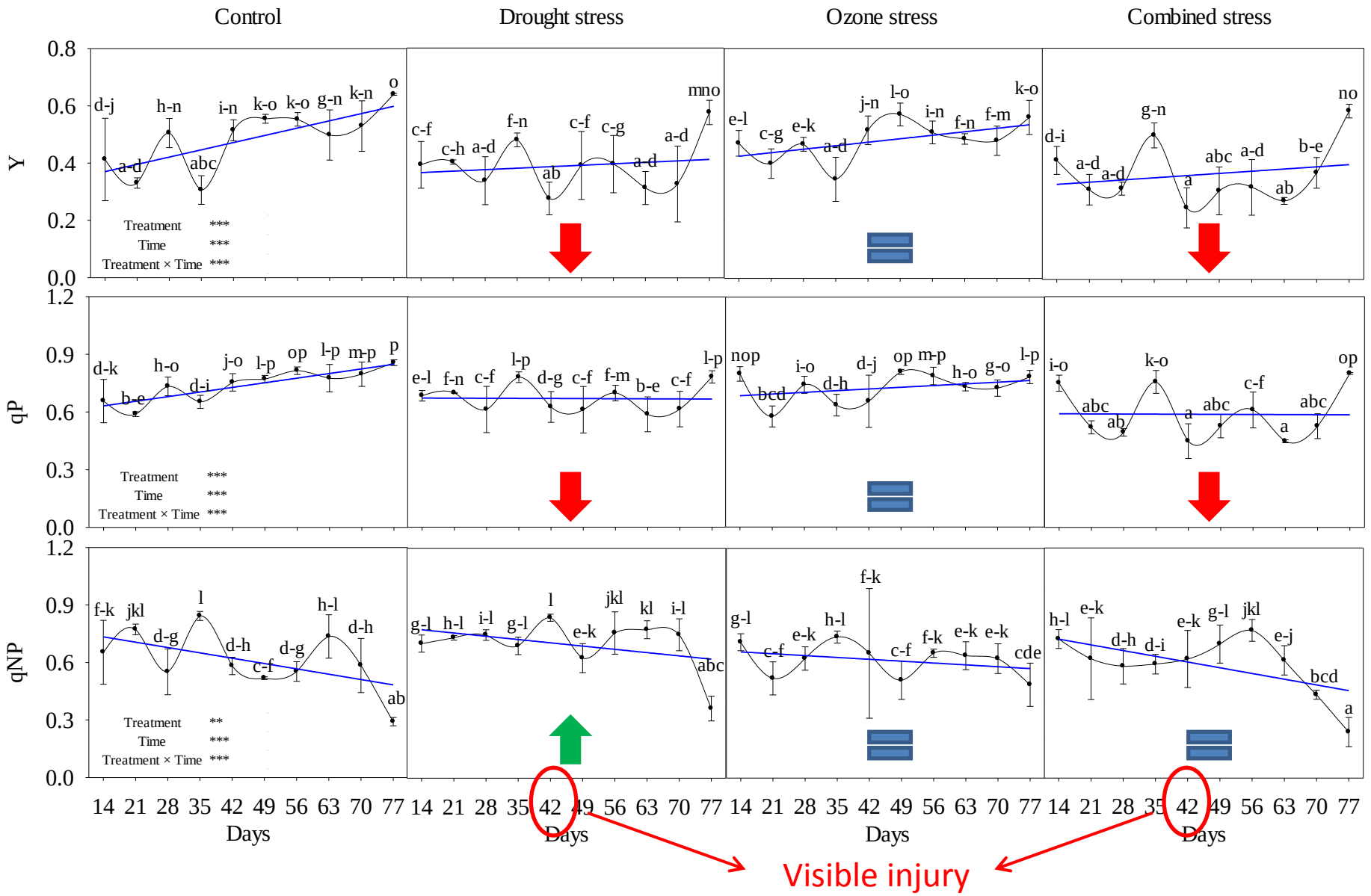


Gas-exchanges (daily profile)

	Drought stress	Ozone stress	Combined stress
A	↓ - 65.3%	=	↓ - 63.7%
g_s	↓ - 72.6%	↓ - 26.0%	↓ - 74.3%
C_i	=	=	=

- Ozone stress: stomatal closure in order to avoid the ozone entry (exclusion)

Chlorophyll *a* fluorescence (weekly profile)



Chlorophyll *a* fluorescence (weekly profile)

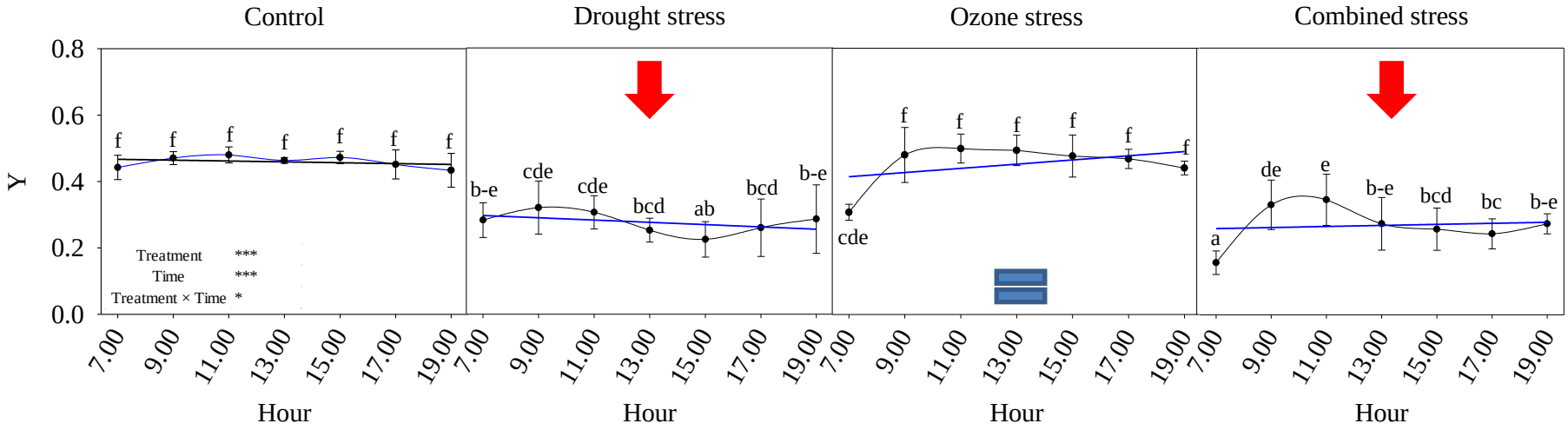
- F_v/F_m did not show significant change during the exposure (all plants showed values inside the optimal range)

	Drought stress	Ozone stress	Combined stress
Y	From the 6th week	From the 2nd week	From the 6th week
	↓ - 19.6%	=	↓ - 25.0%
qP	From the 6th week	From the 2nd week	From the 6th week
	↓ - 9.4%	=	↓ - 20.5%
qNP	From the 4th week	From the 2nd week	From the 2nd week
	↑ +14,6 %	=	=

- Drought stress: photoinhibition with activation of non-photochemical mechanism, but not PSII photodamage
- Ozone stress: no effect on PSII performance
- Combined stress: photoinhibition with no activation of non-photochemical mechanisms, excess energy should be dissipated by other mechanisms, not PSII photodamage

Chlorophyll *a* fluorescence (daily profile)

VI week: visible injury observed



	Drought stress	Ozone stress	Combined stress
Y	From 7.00	From 9.00	From 7.00
	↓ - 39.9%	=	↓ - 41.6%

- Drought and combined stress: photoinhibition but not PSII photodamage
  - Ozone stress: no effect on PSII performance

Biomass partitioning and growth parameters

Growth parameters	Control	Drought stress	Ozone stress	Combined stress	*P*
Total dry weight (g)	41.34 *±11.021* b	17.92 *±3.476* a ↓	36.72 *±6.471* b	18.31 *±0.930* a ↓	**
Shoot/root (g g^{-1})	2.11 *±1.013*	1.40 *±0.090*	0.99 *±0.314*	1.36 *±0.110*	ns
Roots (g)	14.54 *±2.420* ab	8.30 *±2.643* a	20.16 *±7.234* b	8.16 *±0.075* a	*
Stems (g)	17.53 *±6.852* b	5.80 *±0.702* a ↓	12.09 *±1.470* ab	8,08 *±0.680* a ↓	*
Leaves (g)	9.27 *±2.812* b	3.82 *±1.551* a ↓	4.47 *±0.357* a ↓	2.08 *±0.325* a ↓	**
Leaf number	231.33 *±92.230* b	65.67 *±22.745* a ↓	39.33 *±11.504* a ↓	17.50 *±10.112* a ↓	**
Non-syptomatic old leaves (g)	8.74 *±2.761* c	2.68 *±0.605* ab ↓	4.00 *±0.897* b ↓	0.15 *±0.145* a ↓	***
Symptomatic old leaves (g)	0.00 *±0.000* a	0.93 *±0.810* ab	0.00 *±0.000* a	1.83 *±0.570* b ↑	**
Non-symptomatic young leaves (g)	0.52 *±0.051*	0.21 *±0.330*	0.47 *±0.660*	0.10 *±0.100*	ns

- Drought and combined stress: visible at the whole plant level as reduced growth and at the organ level as leaf symptoms
- Ozone stress: reductions only in leaves

PDLWP, lipid peroxidation, proline

Week	PREDAWN LEAF WATER POTENTIAL (Mpa)				P
	Control	Drought stress	Ozone stress	Combined stress	
VI	-0.5 ±0.03 c	-1.4 ±0.10 b ↓	-0.4 ±0.03 c	-2.9 ±0,20 a ↓	***
XI	-0.5 ±0.10 c	-0.9 ±0.08 a ↓	-0.6 ±0.21 bc	-0.8 ±0.10 ab ↓	*

- Only drought and combined stresses reduce PDLWP

Week	MALONDIALDEHYDE (nmol g^{-1} FDW)				P
	Control	Drought stress	Ozone stress	Combined stress	
VI	129.34 ±13.196	127.36 ±16.054	112.80 ±7.487	130.83 ±9.889	ns
XI	161.88 ±10.400 a	202.76 ±9.558 b ↑	189.84 ±9.002 a	210.81 ±1.344 c ↑	***

- Only drought and combined stresses act on lipid peroxidation

Week	PROLINE (mg g^{-1} FDW)				P
	Control	Drought stress	Ozone stress	Combined stress	
VI	0.09 ±0.007 b	0.19 ±0.016 d ↑	0.04 ±0.004 a ↓	0.13 ±0.003 c ↑	***
XI	0.10 ±0.014 a	0.13 ±0.009 b ↑	0.10 ±0.006 a	0.18 ±0.005 c ↑	***

- Only drought and combined stresses act on the proline content

In conclusion:

	Drought stress	Ozone stress	Combined stress
Carbon dioxide assimilation rate	↓	↓	↓
Stomatal limitation	YES	YES	YES
Biochemical limitation	YES	YES	YES
Photodamage	NO	NO	NO
Photoinibition	YES	NO	YES
Non-photochemical mechanism	YES	NO	NO
Growth reduction	YES	YES (only in leaves)	YES
Leaf symptoms	YES	NO	YES
Hydric status	↓	=	↓
Lipid peroxidation	↑	=	↑
Proline	↑	=	↑

- Drought should be considered more harmful than ozone
- Combined stress did not show significant changes in comparison to drought stressed individuals

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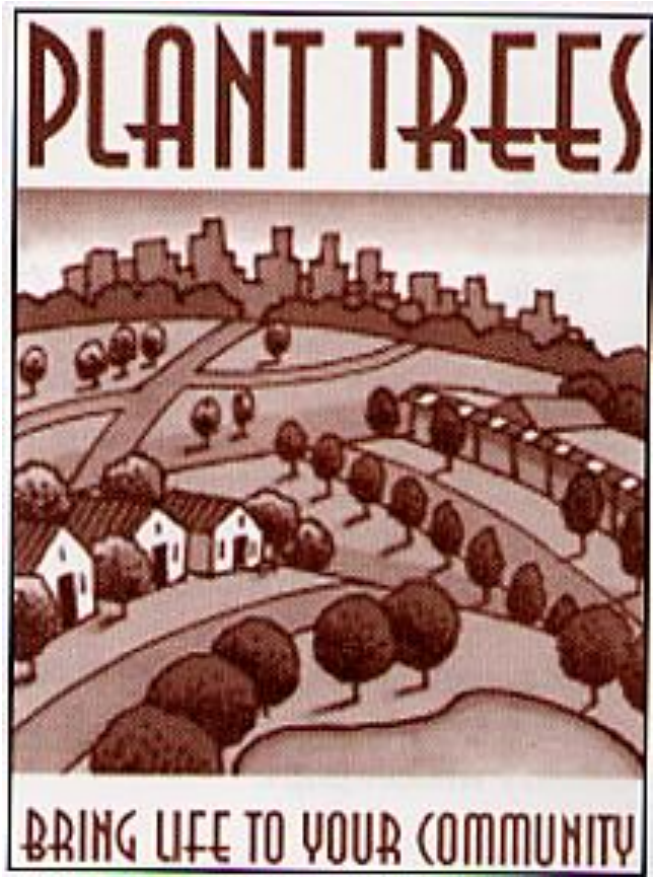

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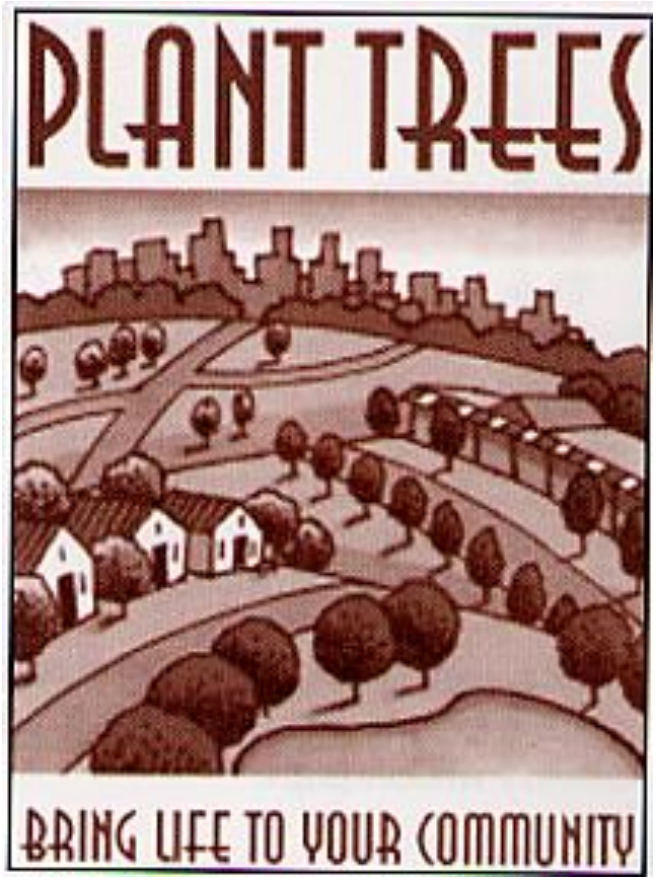

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